MODEL FOR PREDICTION OF HIGHWAY CONSTRUCTION PRODUCTION RATES

By

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Construction production rates are important in many construction management functions. Cost estimating, cost control, scheduling and resource allocation all rely upon production rate data. The prediction of future production rates is essential.

Construction production rates are extremely variable. Historically the prediction of production rates has been difficult and often inaccurate.

This dissertation presents the concept of a factorial model for explaining the variance associated with construction production rates. Production rates are affected by many influencing factors. Identification and quantification of the influencing factors allow a more complete understanding of the work process.

The considerations of factor identification and data collection systems are discussed. Model development and statistical procedures are presented. A comprehensive approach for developing a production rate prediction model is developed.

A demonstration prediction model is developed from a survey data base of production rate observations taken from 60 different highway construction projects in the state of Florida.

CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

Importance of Production Rate Information

Production rates are perhaps the key data element in the construction industry management process. Almost all central management functions depend directly on production rate data. Cost estimating, cost control, scheduling and resource allocation are all based upon calculations which include production rate values. In fact, it is difficult to imagine a construction management function which is not influenced by production rates. Consequently, the effectiveness of the management process is largely dependent upon the quality of the production rate data available. In this instance, quality refers to the accuracy, relevance and timeliness of the production rate data. Figure 1 presents a schematic illustration of the relationship between production rates and the construction management process.

The construction manager relies heavily upon production rate information when performing the following three fundamental project management functions:

1. Estimating

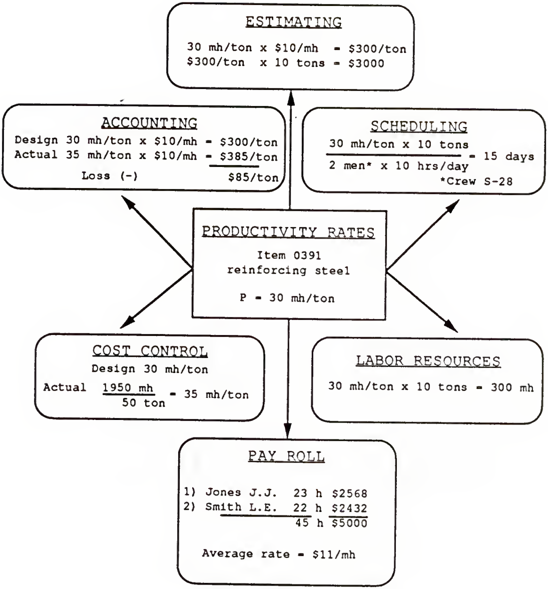

Figure 1. - Relationship Between Productivity Rates and Other Areas in the Construction Management Process, (Herbsman and Ellis 1989) Reprinted with permission of publisher

2. Planning and Scheduling

3. Resource Allocation

Estimates of labor or equipment cost are based upon production rates. Given a certain level of resources, the manager must determine how quickly the work can be performed. Cost also is directly related to production rate. Consider the following example:

Cost Estimating:

Unit Cost = Cost/time x Production Rate

Unit Cost = \$60/hr. x .20 Tons/Hr. = \$120/Ton

Reinforcing

Steel

Crew S-28

Variations in production rates significantly effect cost.

Production rates also determine the time required to perform individual activities. Consequently the schedule and plan for accomplishing the project are based upon production rates.

As an example, consider a calculation of the time required to install reinforcing steel.

Scheduling:

$$\text{Activity Duration} = \frac{\text{Quantity of Work}}{\text{Production Rate}}$$

$$\text{Activity Duration} = \frac{\text{200 Tons}}{\text{.20 Tons/Hr}} = \text{1000 Hrs.}$$

Reinforcing Steel
Crew S-28

Activity times are a direct function of the production rate.

Construction resource management generally involves the allocation of resources to obtain certain time and cost objectives. We want to complete the construction project within a given amount of time and at minimum cost. Since production rates are used in both time and cost calculations, they are an integral part of construction resource management.

Need for Accurate Predictions of Production Rates

Construction is a rather unique production process. In traditional manufacturing cost estimating, planning and scheduling, and resource management are also important management concerns. The manufacturing process involves application of resources and materials to produce a large number of identical products. As the manufacturing process proceeds, production rate assumptions can be refined from actual experience.

Construction, however, is concerned with manufacturing a single one-time product. It is true that similar projects may be done in the future, but the basic circumstances are likely to be different. Variables such as site location, weather, subcontractors change from job to job. Consequently, the construction manager is challenged to estimate and schedule the construction project on the basis of predicted production rates.

Clearly the effectiveness of the construction management is directly dependent upon the quality of the

production rate data. Inaccurate production rate predictions can produce serious problems in the construction process. Pre-bid cost estimates and budgets are only as valid as the underlying production rate information. Coordination of construction activity must be based upon activity durations derived from production rates.

Production Rate Variability

In spite of the importance of accurate production rate information, construction production rates are extremely variable. Rates of production for identical activities vary considerably from project to project. A great deal a variation can even occur on the same project.

Table 1 presents a listing of production rate guidelines used by various state departments of transportation. The activity shown is the Installation of Plant Mix Asphalt Pavement. Installing asphalt pavement was chosen for this illustration because it is a well defined highway construction activity. The actual process is basically the same regardless of where it is performed.

It is interesting to note that even within a given state the predicted production rates are extremely variable. For example, New Jersey DOT uses a value of 50 to 1000 tons per day and Minnesota uses values of 1500 to 7400 tons per day. Even though these highway departments

Table 1. - DOT Production Rates for Asphaltic Pavement Installation

Source	Production Rate Guidelines (Tons/Day)
Arkansas	600
Louisiana	500 - 1000
Minnesota	1500 - 7400
New Jersey	50 - 1000
North Carolina	200 - 1500
North Dakota	600 - 2000
Oklahoma	250 - 1000
Wisconsin	500 - 1000
Wyoming	1500 - 2000
Colorado	500

Source: (Herbsman and Ellis 1988)

rely heavily on production rate predictions, they apparently have been unable to develop more exact estimates of productivity.

Research Objectives

Predicting construction production rates is often difficult. Unlike the controlled conditions found in industrial situations, the construction environment is temporary. Each project is likely to involve a unique combination of factors such as location, weather, site conditions, and other project parameters. All of these unique factors are potential modifiers of individual activity production rates. Acceptable accuracy in predicting production rates can only be achieved by taking into account all of the principal factors influencing the work activity.

The objective of this study was to develop a model building system for the prediction of highway construction production rates. To be valid, such a model must provide a mechanism for identifying influencing factors and quantifying their effect on the production rate.

It was apparent from the onset that each different construction activity might be subject to a unique set of influencing factors. Any model for predicting production rates would then have to be custom tailored to a specific activity. Therefore, research emphasis was directed towards developing a general modeling procedure rather

than a single specific model. This approach hopefully will permit a more general application of the research results.

The production rate modeling system should give consideration to several key subjects. The following are some of the areas which must be addressed:

1. Data Collection Techniques
2. Classification and Recording of Data
3. Data analysis and Management
4. Identification and Measurement of Influencing Factors
5. Model Development
6. Model Validation

Considering the broad scope of the problem, the systems approach appears to be the correct choice. Each of these separate areas should be investigated and integrated into a complete system. The complete model building system would then be applicable to the task of predicting and analyzing production rate information in a wide range of construction situations.

Research Methodology

The basic theory which was to be explored in this study is that construction production rates can be predicted by a model which includes the principle factors.

In general, we are concerned with the following relationship:

$$P = f\ (F_1,\ F_2,\ \cdot\ \cdot\ \cdot,\ F_k)$$

Where P is the expected mean value of the production rate and F_1, F_2, . . ., F_k are the variables influencing production.

If the influencing factors can be identified and their relationship to the production rate determined, then the production rate can be predicted. Additionally, the accuracy of the prediction can be estimated using inferential statistical methods.

In order to accomplish the research objective, the investigation was organized into four phases as follows:

Phase I literature survey

Initial research concentrated on acquiring a library of information developed by previous researchers and scholars. The objective was to develop a more comprehensive understanding of the problem and to begin the study with all available information. The literature survey focused on three primary areas:

1. Analysis of the Highway Construction Process
2. Construction Productivity Measurement Studies
3. Statistical Analysis and Modelling Techniques.

Phase II analysis of the highway construction process

It was evident from the onset that any attempt at model building should be based upon a through understanding of the underlying process being considered. Therefore, it was essential that the model building begin with a detailed analysis of the process being considered.

Analysis of the highway construction process was focussed on developing information about several specific subjects. These areas of interest are as follows:

1. Basic Activities Involved in the Work Process
2. Types of Projects Performed
3. Factors Which May Influence Production
4. How Highway Construction Compares to Other Types of Construction

Phase II statistical analysis and model development

Based upon information gained from the first two phases, statistical analysis procedures and modelling techniques were examined. A comparison of different procedures was made in order to determine the one best suited for analyzing and predicting construction productivity. A preliminary model was developed for predicting the construction production rate. Attention was given to both theoretical development and to use of advanced computational computer software such as SAS.

Phase IV model demonstration

The final research phase involved testing the statistical procedures and model with real production data. The object was to perform trials of the modelling system on a variety of highway construction situations. The experimental research data were obtained from highway construction projects throughout Florida. A total of 60 projects was sampled, which resulted in 645 production rate observations.

Testing of the model resulted in further refinement and recommendations for future research. A flow chart of the research procedure is presented as Figure 2.

State of the Art--Factorial Model Theory

The factorial model for productivity has been applied quite extensively in industrial management. Currie presented a comprehensive treatment of the subject within an industrial context (Currie 1963). Only recently, however, has the theory been applied to the construction industry.

Initial research on production rate factors in construction has been generally limited to investigating only a single factor. Weather appears to be the most popular subject. The weather effects on construction productivity have also been studied (Clapp 1966) and (Grim 1974). A study released by the National Electrical Contractor Association (NECA) in 1974 has become the industry reference for predicting the effects of temperature on construction labor productivity (National Electrical Contractors Association 1974).

However, investigations by Horner and Whitehead sought to identify all factors which had a significant effect on construction labor productivity (Horner and Whitehead 1984). The most recent and comprehensive treatment of the subject to date appears to be by Thomas (1988).

PHASE I LITERATURE SURVEY	
Scope	Chapters
Historical Background and Current State of the Art	1. Introduction

↓

PHASE II ANALYSIS OF HIGHWAY CONSTRUCTION PROCESS	
Scope	Chapters
Developing the Understanding of the Underlying Process	2. The Highway Construction Process

↓

PHASE III STATISTICAL ANALYSIS AND MODEL DEVELOPMENT	
Scope	Chapters
Development of Procedures and System for Production Rate Prediction Modeling	3. Collecting Data on Construction Production Rates 4. Data Management and Data Base Design 5. Model Development 6. Exploratory Data Analysis 7. Statistical Analysis Procedures

↓

PHASE IV MODEL TESTING AND EVALUATION	
Scope	Chapters
Case History Testing and Evaluation of Modeling System	8. Demonstration Model: Case History 9. Summary and Conclusions

Figure 2. – Flow Chart of the Research Procedure

Thomas addresses the concept of using a factorial model to describe production rates. The research, however, was limited to dealing with the effects of weather on building construction activities. The data used consisted of production measurements obtained on three building construction projects in central Pennsylvania. All three projects were multi-story, steel frame, masonry exterior structures. A total of 78 observations of production were obtained from the three projects.

Each day the amount of production achieved was recorded as well as the temperature and relative humidity at 1:00 p.m. The production rates were reported as performance ratios, which were defined as:

$$\text{Performance Ratio (PR)} = \frac{\text{Actual Productivity}}{\text{Expected Productivity}}$$

Clearly the object of the research was to establish the relationship between weather (temperature and humidity) and production rate. According to Thomas, multiple regression analysis of the data revealed the following equation:

$$PR^1 = 9.448 + 0.0518/T - 2.819 \text{ Int} + 3.89 \times 10^{-37} e^{H}$$

where

PR1 is the predicted daily performance ratio

T is the air temperature at 1:00 pm in degrees F

H is the relative humidity at 1:00 pm as a %

This relationship is said to have resulted in a R^2 value of 0.649 and an F statistic of 17.7. The relatively high F statistic indicates that there is a statistically significant relationship between the model and the dependent variable. However, the R^2 value indicates that only about 65% of the variability was accounted for with the equation.

Thomas clearly demonstrates the validity of the factorial model concept but also indicates the need for additional research in several key areas. Obviously factors other than weather exist and should be included in the model. How do we identify and measure the effect of these factors? Which statistical analysis and linear modelling techniques are best suited for construction productivity. Thomas confirmed the need for additional research (Thomas 1987). In his paper he states,

> Analysis techniques range simple to complex. A great deal of development work needs to be done in this area as well, but good quality data are need first. A comprehensive study of the literature verifies that essentially no progress has been made in any of these fundamental areas. (page 624)

Summary

Production rates are an essential information element in the construction management process. In construction, many management decisions are based upon production rate predictions. Being able to accurately predict production rates improves management efficiency.

This research study deals with the development of a factorial modelling system for improving the accuracy of production rate predictions. Data collection, statistical analysis and model building techniques are reviewed. A preliminary model was developed and tested with extensive observational data obtained from recent construction projects.

CHAPTER 2

THE HIGHWAY CONSTRUCTION PROCESS

Introduction

Any attempt at modeling should be based upon a thorough understanding of the underlying process. One of the most common statistical traps is the confusion of correlation with causation. Preference must be given to a model which actually describes the process being considered. Therefore, it is essential that model building begin with a detailed analysis of the process being considered.

In the case of highway construction, several fundamental understandings must be developed. The basic work activity components of the construction process must be identified and described. Additionally, the relationship between activities must be defined. Finally, we need to generate a list of potential factors which will influence activity production rates.

In general, we are interested also in the similarities and dissimilarities between highway construction and the building construction process. This

knowledge will facilitate the adaptation of the modelling system to other construction categories.

The Highway Construction Work Process

The highway construction process proceeds in a linear fashion over the length of the roadway with one operation following another. The whole process consists of a relatively limited number of activities.

An interesting comparison can be made between the highway construction process and that of a manufacturing assembly line. In the manufacturing industry the product is moved from one fixed work station to another along an assembly line where the same activities are repeated over and over again at each station. The highway construction process is similar with the exception that the highway is a fixed assembly line. Therefore, the work stations (machines) must travel along the stationary assembly line.

In simple terms the highway construction process is composed of four basic operations. Figure 3 present a schematic illustration of the basic highway construction process. Table 2 provides a listing of basic highway construction work activities.

Survey. The first step is the establishment of the alignment and elevation grade of the new roadway. This is accomplished using engineering surveying procedures to transfer the design data from the engineering drawings to the existing terrain. The survey proceeds from control

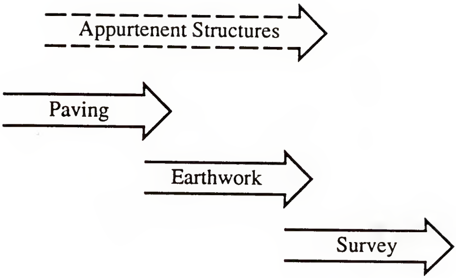

Figure 3. – Illustration of the Highway Construction Process

Table 2. - Listing of Basic Highway Construction Work Activities

Activity	Unit of Measure
Clearing and Grubbing	Acres
Excavation	Cubic Yards
Stabilizing	Square Yards
Base Construction	Square Yards
Surface Treatment	Cubic Yards
Concrete Pavement	Cubic Yards
Milling	Square Yards
Plant Mix Asphalt	Tons
Storm Sewers	Lineal Foot
Gurband Gutters	Lineal Foot
Sidewalk	Square Yards
Sod	Square Yards
Guardrails	Lineal Foot

reference points and results in a series of grade states. It is these layout states which serve as position controls for the construction process.

Earthwork. The heart of highway construction is the earthwork activity. This consist of reworking the existing terrain to conform to the alignment and grade required for the new road. Excess earth material is excavated and then transported along the roadway to an area requiring fill or for waste at preselected locations.

Excavation, hauling and dumping is typically accomplished with large earth moving equipment. Excavation is frequently performed by an excavating-hauling unit called a scraper. The scraper consist of a tractor which pulls a load carrying called a bowl. The bottom of the bowl contains a blade which shaves off the existing earth. As the unit moves forward, the earth is forced up into the bowl. The operator riding in the tractor attempts to maintain a constant loading speed by varying the depth of cut. The bowl and the blade are raised and lowered to change the depth of cut. When full the scraper hauls material to the fill area where the earth is dumped out the back of the bowl.

Installation of earth fill consists of spreading the material by a dozer tractor or motor grader and stabilizing the material by compaction. As the cut or the fill approaches the required elevation, a work process called grading begins.

Grading is the process of bringing the earth road bed to the design finish elevation. Grading requires a skilled motor grader operator who must control the grader blade in order to achieve the required surface elevation within a strict tolerance. The grader operator works to grade stakes or "bluetops" which are placed in the roadway with the top of the stake set at the desired finish grade elevation of earth.

Paving operations. The pavement surface of the roadway is composed of either portland cement concrete or asphaltic concrete. Both materials are usually plant mixed and transported to the point of application. The actual installation process of both materials is similar. Both asphaltic pavement and concrete pavement are spread over the road surface by a paving machine. These paving machines receive the plant mix material from the transport unit and spread the material over the roadway as the machine travel along. With both the asphalt and the concrete pavers the operator must be skillful in maintaining the correct pavement thickness and smoothness.

Appurtenant structures. In addition to the roadway construction, highway projects commonly include the construction of appurtenant structures such as bridges, culverts, barricades and drainage systems. The construction of these appurtenant structures in generally undertaken as a distinct work process which must tie in to the work schedule established for the roadway work. Many

of the structures more closely resemble the work process used in building construction than that of highway construction.

Factors Effecting the Work Process

Classification of Factors

The number of different factors which may effect construction production rates is very large. This is a result of the dynamic nature of the construction process. Generally each product (or project) is unique and is produced in a different location. The set of potential influencing factors may be different for each project considered. Therefore, developing a basis for analysis can be difficult.

Consequently, a system for classifying factors is needed. The following system (Herbsman and Ellis 1989) provides a mechanism for rationally organizing influencing factors. Factors which may effect production rates are designated as Construction Production Influence Factors (CPIFs). For classification purposes, the CPIF's can be separated into three distinct groupings as follows:

1. Project Factors
2. Site Factors
3. Organization Factors

Project factors are influencing factors which are directly related to the particular product which is to be constructed. This would include project parameters such

as the type of construction, size of the project, specifications, and construction details. These projects factors would be valid for a specific project regardless of the choice of site or construction organization.

Site factors are derived from physical conditions of the site at which the project will be built. Site factors might include items such as the geographic location, type of earth, weather, local traffic conditions and adjacent land use. These site factors are unique for a specific site and are valid for any project which might be considered at that site.

Organizational factors are the influencing factors resulting from the organizations involved in the construction process. This includes all relevant parties such as the owner, construction manager, inspecting authority and builder. Significant organizational factors might include the level of skill of the workmen, supervisory skill, degree of inspection, safety and managerial expertise. These are factors which primarily are related only to the people side of the process.

It is important to note that each of the three different classes of influencing factors is not necessarily independent of the other two. This means that the effect on production of one class of influencing factors may depend upon the existence of other influencing factors of another class. For example, the effect on activity production rate resulting from any of the site

factors may be directly related to the type of project to be constructed.

The statistical importance of this interaction between factors will be discussed further in Chapter 7 which covers statistical analysis procedures.

The classification of factors assists in the identification of CPIFs and in the management of CPIF data. An exact determination of classification is not absolutely necessary. For instance, certain factors relating to project site layout might originate from the physical limitations of the specific site, or from the builders plan for site layout, or might be dictated by the particular project.

Figure 4 presents a schematic diagram showing a CPIF classification system.

Relating CPIFs to Work Activities

Matching potential CPIFs to specific work activities is an essential prerequisite to predicting activity production rates. Identifying potential influencing factors requires a careful and objective analysis of the particular work activity being considered. The most desirable approach involves input from those persons directly involved in the work process. The project superintendent, crew foreman and machine operator should all contribute to the development of the list of potential influencing factors. A systematic approach will produce the best results.

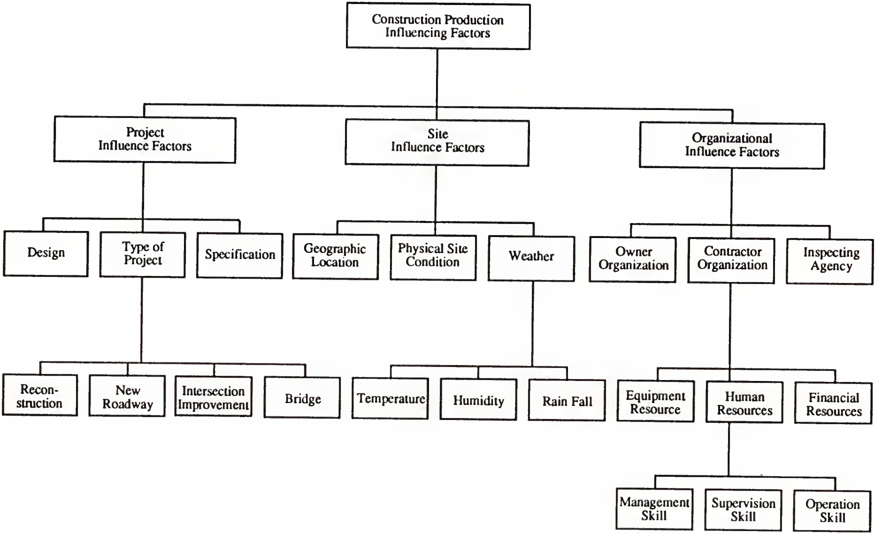

Figure 4. – Schematic Diagram of a CPIF Classification System

The most effective method appears to be for the researcher to interview the participants using a checklist. The checklist provides a standard format for soliciting input. Figure 5 presents an example of a CPIF checklist. After obtaining input from the work participant, the researcher then develops a preliminary list of influencing factors. This list of factors will be used in designing the production rate data collection procedure and in model formulation.

Comparison of Highway Construction with Building Construction

It should be noted that the highway construction process differs considerably from that of traditional building construction. Highway projects generally involve only a relatively small number of basic work activities. Each of these activities is changed very little from project to project.

Building construction on the other hand, generally involves a much larger number of distinct work activities. The scope of construction specialties required for a typical building project today far exceeds that of a road project. Except in certain cases where the same structure is being repeated each building construction project requires a customized approach to its basic work activities.

Highway construction is also more of a linear process. Highway construction proceeds along the roadway

Construction Production Rate Influencing Factor

CHECK LIST

Activity No.: ______________________ Date: __________

Activity: ______________________________________

Project	Site Factors	Organization Factors
☐ Project Type	☐ Location	☐ Inspection
☐ Specifications	☐ Layout	☐ Supervision
☐ Materials	☐ Adjacent Area	☐ Operator Skill
☐ Size	☐ Weather	☐ Equipment
☐ ________	☐ ________	☐ ________
☐ ________	☐ ________	☐ ________

Figure 5. – Example of CPIF Checklist

from beginning to end. In certain cases, vertical building construction might be considered a linear progression, but for the most part building construction is a complex sequence of interdependent activities.

The concept of influencing factors applies equally to both building construction and highway construction. However, the complexity of the building construction process makes the production rate modelling system more complex. The simplicity and standardization of the highway construction process facilitate development of the production rate modelling system.

These characteristics of highway construction (limited number of uniform activities) facilities the study of factors effecting production rates. Uniformity in the work activity is essential in acquiring an adequate research data base for analysis. If the work activity remains unchanged from project to project, correlation of the production rate observation is possible.

Summary

Highway construction process involves four fundamental operations:

1. Surveying
2. Earthwork
3. Paving
4. Constructing Appurtenant Structures

The process consist of a relatively small number of basic work activities which are repeated in a linear fashion.

Understanding this process is an important part of the model building procedure.

A variety of factors may effect the highway construction work activities. These Construction Production Influencing Factors (CPIFs) can be classified into three main groups.

1. Project Factors
2. Site Factors
3. Organizational Factors

Classification assists in identification and in data management.

Identification of potential CPIFs involves input from the participants in the work process. Final verification of the significance of potential CPIFs is based upon statistical analysis of the production rate observation data.

CHAPTER 3

COLLECTING DATA ON CONSTRUCTION PRODUCTION RATES

Introduction

Production rate measurement and recording is an essential prerequisite to the development of a prediction model. Accurate and timely data are required. The structure of the model and its predictions of future production rates are based upon historical production rate data. The validity of the model and the accuracy of predictions are directly dependent upon the quality of the input data. Incomplete and erroneous data will produce unsatisfactory results. Therefore, careful consideration must be given to the many issues associated with the collection of production rate data.

Certainly there are several fundamental issues which must be decided. How are the production rates to be measured? Which activities should be observed? What form of sampling program should be used? Each of these issues will be addressed in this chapter with respect to the development of the production rate prediction model.

General Requirements for the Measuring System Criteria

The following criteria are suggested for a meaningful measurement system (Bain 1982):

1. Validity
2. Completeness
3. Comparability
4. Inclusiveness
5. Timeliness
6. Cost-effectiveness

These criteria were derived in an industrial context but they apply equally well to construction. They provide useful guidelines for evaluating and selecting production rate measuring procedures.

Validity. Validity measures of production rates indicate actual changes in the ability production rate. The choice of units of measure may result in validity problems.

For example, consider the measurement of the production rate for the installation of concrete pavement as shown in Table 3. If production is measured in units of square yards, data indicating differences in production rates may be misleading. Pavement with significant differences in thickness would have been grouped together. The unit of measure (square yards) is not a good choice for concrete pavement. A unit which more accurately represents the work effort would be volume or cubic yards.

Table 3. - Comparison of Production Rate Units of Measure

Project	Average Production Rate per Day SY	CY
A	2790	620
B	3870	430
C	3420	570

Completeness. Meaningful measures of production rates must take into account all significant factors which effect the work activity. Comparing asphalt pavement production rates for a project located in an urban, highly congested area with that of a project located in a rural area is meaningful only if the environmental factors are identified. The measurement and reporting process must also include the influence factors associated with the work produced.

The identification and qualification of CPIFs provides a basis for comparison of activity production rates.

Comparability. Much of the value obtained from production rate measurement results from comparison. We would like to compare current production rates with past values. We might want to compare production rates achieved on one type of project with the rates on another type of project. Also, after having made a particular management decision, we would like to compare the new production rates with the previous rates.

Standardization of the data collection techniques is mandatory, if valid comparisons are to be made. Thomas also expressed this opinion (Thomas 1987):

> Standardized data collection is needed to ensure consistency. Ways of combining data from different projects need to be found because reliable analyses cannot be done using 30-60 data points, as may be the case if data from only one project were used.

Each organization must develop a standard procedure for production rate data collection. The method of collection, measurement and recording must be uniform. ONly then can valid comparisons be made over the entire data base.

Comparability of the data is enhanced by the inclusion of factorial data in the production rate collection system.

Consider production rate data for the work activity of general excavation. Production rate observations obtained from two projects with differing working conditions can be compared only if information concerning the appropriate CPIF's is also known.

For example, Table 4 presents production rate observation data for general excavation. The mean production rate for Project A is 1167 cy/day. The mean for Project B is 780 cy/day. It is not possible to make an informed managerial interpretation without the factorial data. In this case, given the relevant CPIF data, we would suspect that the difference in the means values is the result of the three days of rain which occurred on Project B.

Inclusiveness. The production rate modeling system should include work activities which contribute significant information used by management in obtaining organizational goals. Most likely the cost of data collection and analysis will preclude including all

Table 4. - Example of Production Rate Data Comparability

Obs. No.	Project	Excavation Production Rate cy/day	Influence Factors				
			F1 Material Type	Rain	F3 Project Type	Crew	F5 Total Quantity (Range)
1	A	1120	SC	NO	NC	S-28	4
2	A	1240	SC	NO	NC	S-28	4
3	A	1090	SC	NO	NC	S-28	4
4	A	1150	SC	NO	NC	S-28	4
5	A	1120	SC	NO	NC	S-28	4
6	A	1280	SC	NO	NC	S-28	4
7	B	520	SC	YES	NC	S-28	4
8	B	410	SC	YES	NC	S-28	4
9	B	380	SC	YES	NC	S-28	4
10	B	950	SC	NO	NC	S-28	4
11	A	1240	SC	NO	NC	S-28	4
12	A	1185	SC	NO	NC	S-28	4

activities. Therefore, a decision must be made as to which activities to include. Selection criteria should be developed for prioritizing work activities.

Assigning a rank in accordance with the activities importance to the organization appears to be a logical first step in the selection process. The number of activities to be measured would ultimately be based upon budgetary considerations.

Timeliness. Timeliness is an essential criteria for all managerial information. The production rate measuring system should provide information which is as current as practical. Timely measures of organizational performance are essential for improving productivity. Post completion evaluations may be useful for planning future projects but they are of no value for the project just completed.

This means that for most construction applications the timing of the data collection-analysis-reporting cycle should be a matter of days not weeks. The normal monthly accounting period is probably too long a turn around time. Mangers who have the primary responsibility for project planning and scheduling will require at least weekly production rate updates. Managers in a more passive role such as owner's representatives, may be satisfied with monthly updates.

Cost-Effectiveness. Collecting data on production rates should be based upon overall cost-effectiveness just as with any other management information system. The

degree of detail and the number of activities to be included in the system must be decided by each organization. Each participant in the construction process will have different requirements for production rate information. Therefore, the production rate modeling system is expected to be adjusted by each user to the organizational needs.

Measuring and Reporting Completed Work

General Considerations

The method of measurement and the reporting documentation are most effective when matched to the project and organizational situation. A number of possible measuring techniques exist. Each has advantages and disadvantages. The following three different methods are available for measuring completed work (Thomas and Kramer 1988):

1. Units Completed
2. Percent Completed
3. Level of Effort

Each of these methods will be discussed in the following sections.

United Completed

Actually counting or measuring the quantity of work accomplished is the most direct method of measurement. Physically measuring or counting the completed work can be the simplest approach.

For the most part, highway construction work activities are compatible with this form of measurement. We can determine by direct measurement or count how much of each work activity has been accomplished. For example, the number of cubic yards of pavement installed can be determined from actual measurement. The number of drainage inlets installed can be actually counted.

Measuring the units completed provides an accurate, simple method of measurement. However, there are a few disadvantages. First, actually measuring work quantities on the project site can be time consuming and costly. Secondly, for certain items physical measurement may not be readily obtainable. Some of the appurtenant work on highway projects more closely resembles building construction. Work activities are likely to be partially completed.

For example, consider a concrete bridge deck. A significant amount of preparatory work must be accomplished prior to the final placement of concrete. If we count only completed work units, the work effort involved in forming and reinforcing will not be considered until the deck is complete.

The units completed method may not be appropriate for activities which involve several subtasks.

Percent Complete

The percent complete method consist of a subjective opinion. Usually the job superintendent and the owner's representative agree on how much of the particular activity has been accomplished.

This method is useful with some activities which may be difficult to measure. However, the accuracy of the technique is obviously dependent upon the judgement of the measurer.

Level of Effort

One way to make the percent complete method more objective, is too divide the work activity into its subtasks. Each subtask is then pre-assigned a portion of the overall work effort. This weighing of the subtask is sometimes called a rule of credit. For example, the concrete bridge deck previously mentioned might be subdivided into the following levels of effort.

Work activity: concrete bridge deck

Subtask	Rules of Credit
Formwork	0.50
Reinforcement	0.15
Concrete Placement	0.25
Form Removal	0.10

In this case, as each subtask is completed its portion of the overall activity may be counted.

The advantage of the level of effort procedure is that it provides greater accuracy and objectivity in the measurement of work activities which are difficult to measure (Thomas and Kramer 1988).

Choosing the Appropriate Method

Each of the measurement options have advantages and disadvantages. Selection should be made with consideration for the characteristics of the particular activity. However, it is essential that the measuring procedure reflect what has actually occurred at the project site. Table 5. presents a summary of the measurement methods with advantages and disadvantages.

Reporting the Data

Daily Reports

Reporting production rate data on a daily basis is an option available to the contractor. The daily submission of time reports and equipment usage reports is routine. The reporting of completed work quantities could be conveniently combined with the organization's standard daily reporting documentation.

The advantage of daily reporting is the level of detail provided and the timeliness of the information. The disadvantage is that measuring and reporting requires supervisory time and performing this function daily may be too costly to justify.

Table 5. - Methods of Quantity Measurement

Method	Criteria	Advantages	Disadvantages
Units Completed	Well-defined scope	Most detailed and accurate	Cost of data collection
	Output determined quickly by counting or elementary math	Does not rely on subjective opinions or evaluations	
	Relatively few subtasks	Claimed output can be readily verified	
	Short duration for completing each unit of output		
	Single craft or trade		
Percent Complete	Relatively minor tasks where reasonably accurate estimates can be made	Simple	Can be very inaccurate and misleading
		Inexpensive	
		Quick	
Level of Effort	Activities involving overlapping subtasks	Greater detail and objectivity than simply estimating how much work was done and less expensive than counting or measuring the units completed	More involved than simply estimating the percent complete
	Subtasks must be measurable or their status easily defined		
	Best suited where there is a large number of similar commodity items, and the work will be ongoing for an extended period of time		

Source: (Thomas and Kramer; 1988)

Monthly Reporting

Another option is to report production rate information as a part of the normal payment estimate process. Highway construction projects are typically bid and paid on the basis of unit prices. Calculation of the monthly payment estimate involves a determination of the quantities of work accomplished. If the time spent working on the work activities can be verified also, the production rate information should be available from the data worked up for payment estimates.

The use of a CPM type project schedule with the updating of actual start and finish dates also would provide a means of reporting time spent. Some consideration must, however, be given to insuring compatibility between the activities selected for production rate modeling and those activities making up the payment and scheduling systems.

Figure 6 presents an example of a monthly payment estimate/production rate report.

The advantage of monthly reporting is that it is less costly. However, information is less timely.

Pay Estimate/Production Rate Report

Project: Resurface I-75
No: 410005-IA-002

Period Ending: 30 JUN 88
Superintendent's Signature

____

Activity No.	Activity Description	Unit	Total Quantity	Completed This Period	Days Worked	Comments
2105	Milling	SY	320000	27150	18	
2211	Asphalt Pavement	Tons	75000	5600	8	3 Days Rain
2504	Guardrail	LF	6000	2100	12	

Figure 6. – Example Monthly Pay Estimate/Production Rate Report

Sampling Considerations

Activity Selection

Measuring and analyzing production rates for all activities will probably be too costly for most organizations. Therefore, a selection criteria should be developed for choosing those activities which are to be measured. The selection criteria should be based upon the objectives and goals of the organization.

Establishing a priority ranking for each activity can be done based upon the following criteria:

1. Amount of Work
2. Critical Path

The amount of work refers to the proportion of work performed by the organization which is represented by the activity. For example, asphalt pavement may represent 10.2% of the organization's total annual volume. Storm drainage may represent only 1.2% of the total effort. Each activity is graded based upon historical records.

The second criteria pertains to the activity's occurrence on project critical paths. Some activities may represent only a small percentage of the total work effort but still be significant because of their impact on project scheduling. Therefore, these critical scheduling activities may also be important candidates for production rate modeling.

Each activity can be assigned a priority ranking derived from a priority weighing system. The equation for calculation the ranking can be expressed as

$$A = Ww\ P + Wc\ N$$

where

A = activity ranking

Ww = weight assigned to work percentage

P = activity's percentage of the total work

Wc = weight assigned to critical path

N = frequency of occurrence on critical path

Activities are submitted to the production rate modeling system on the basis of their ranking or A value. The total number of activities to be handled by the system is determined by management generally on the basis of cost.

Randomization

In an ideal situation we would like to collect all production rate data for any activity of interest. Having a complete historical data base provides the strongest possible input for the prediction model.

Economics, however, may preclude the collection of all production rate data. In this case, we can make predictions concerning future production rates by using a sample of the total work.

Suppose that the production rate modeling system is being developed by a state highway department. During any

given year hundreds of projects are performed throughout the state. It is not possible to make observations on all projects. Therefore, only a small number of projects will be observed. The selection of projects should be made randomly.

That is, each project should have an equal chance of being selected. If we do not insure randomization, we can not insure the validity of our inferences about the data analysis.

Selecting a project because it is of particular interest may serve management's immediate needs, but will also introduce challenges to the sampling system's validity. If conclusions are to be made concerning the entire population of projects from a sample of projects, then the sample must be randomly selected.

The assumption of randomization is a fundamental prerequisite to the statistical analysis and regression procedures used in the evaluation of the production rate data. Analysis procedures will be discussed further in Chapter 7.

Sample Size

How many sample observations should be made? This very practical question must be confronted by each user of the prediction model. Making observations and analyzing the data cost money. In general we would like to work

with the smallest sample size which will still produce acceptable prediction model results.

Logically, we might expect that larger samples would more closely match the overall population. Further, we might suppose that our prediction ability to predict the populations statistical parameters from a sample would depend also upon the variability of the values.

It turns out that the number of sample observations required is determined by two factors: variability of the population values, and the desired prediction accuracy. The sample size required may be estimated by the following equation (Scheaffer 1986, 237):

$$n = \left[\frac{Z_{\alpha/2}\ \sigma}{\beta} \right]^2$$

where

n = number of sample observations required
z = a standardize normally distributed variable which is a function of probability. (values of z are commonly given in statistical tables for normal probability distributions.)

α = rejection region chosen for the z value

σ = variance

β = desired prediction confidence interval

For example, suppose we are interested in predicting the daily production rate for the highway construction activity, Asphalt Pavement Installation. We would like our prediction to be within 100 tons/day of the actual value. Furthermore, we do not want to encounter an

actual value which is outside of our 100 ton/day confidence interval more than 10 percent of the time. From past historical data or perhaps we have done some preliminary test, we estimate the variance to be 22500 $tons^2/day^2$.

Therefore, the values for the sample size equation are

$z_{.05} = 1.645$

$\sigma = 150$ tons/day

$\beta = 100$ tons/day

It follows that

$$n = \left[\frac{1.645*150}{100}\right]^2 = 24.35$$

In this example, 25 observations must be obtained to obtain the desired results.

It is important to note that the preceding estimate of sample size is based upon the assumption that the production rate values are normally distributed about the mean. However, with construction production rates we have reason to believe that the frequency distribution of the values is not normally distributed. In fact, the frequency distributions of production rate observations appear to be skewed to the right of the mean.

Therefore, our estimate is not as precise as it would be if the assumption of normality was valid. The issue of normality will be discussed further in Chapter 7.

Summary

The systems used for collection of production rate information are important to the success of the production rate prediction model. Observations of actual production rates and corresponding factorial measurements are the input data used by the model to generate production rate predictions. The accuracy of the model's predictions and its cost effectiveness depend directly upon the data collection system.

In general, the production rate measurement system should conform to the following criteria:

1. Validity
2. Completeness
3. Comparability
4. Inclusiveness
4. Timeliness
5. Timeliness
6. Cost - Effectiveness

The method selected for measuring the production rate should be selected after considering these criteria. Three measuring techniques which are appropriate for production rates are:

1. Units Complete
2. Percent Complete
3. Level of Effort

The number of observations which should be obtained is a function of the desired prediction accuracy, data

variability and the number of factors considered. Selection of which activities to include in the model can be made on the basis of relative significance to organizational objectives.

Data management and storage considerations will be reviewed in the next chapter.

CHAPTER 4

DATA MANAGEMENT AND DATA BASE DESIGN

Introduction

Data management and storage are important considerations for the construction production rate model. The production rate model will deal with substantial amounts of data. The efficiency and utility of the model will largely depend upon the design of the data management and storage systems.

This chapter will cover data management concepts as they apply to production rate data. The structure of the data base will be discussed. Also, the concept of integrating the production rate model within the organization's management information system will be presented.

Data Base Structure

A data base is simply the logical arrangement of information. Usually, the following conventions are used in describing the elements in the data base structure (Stair 1984):

Characters -	the smallest single component, either alpha, numeric or special
Fact -	assembled from characters, facts are words or numbers
Record -	a collection of related facts
File -	a collection of related records

With regard to the production rate observational data, facts are the observed production rates and the CPIFs. A record would consist of all facts relating to a single observation. A data file might consist of all observations of a specific activity. An illustration of this arrangement is given in Figure 7.

Although there are several possible logical arrangements of data elements, a relational data base structure is best for production rate data. The relational data base structure relates data in a tabular form. In its simplest form the relational data base model organizes data into a two dimensional table. Each row of the table is a record of information. Each column represents a specific class of facts.

The relational data base structure allows efficient access to the information in the form of data queries. Suppose, for example, we wish to review all of our production rate observations taken from a specific type of project. A query to the data base is made after stipulating the selection criteria. The resulting report

A File

A Record

Activity: 02485 General Excavation

Observation Number	Production Rate (cys)	Date	Work Quantity (Range)	Project Type	Project Size (Range)	Weather	Material Type	Traffic Volume
1	2007	102286	5	NC	3	F	SC	M
2	1349	103186	5	NC	3	F	SC	M
3	600	032487	2	RC	2	R	SC	M
4	1059	052687	3	RC	2	F	SC	L
5	928	052787	3	RC	3	F	C	L
6	1871	053187	4	NC	4	F	S	M
7	1924	071487	4	NC	4	F	S	L
8	1785	071787	3	NC	2	F	R	H
9	1110	090887	2	RC	2	F	S	H
10	1002	091187	2	RC	1	F	S	H
11	425	092487	1	I	5	F	SC	L
12	1229	100587	3	RC	2	F	SC	L

Figure 7. – Illustration of the Basic Data Structure for Production Rate Observations

is a list of all observations made from the specified type of project.

The relational data base structure also allows for efficient statistical analysis of the data. Statistical and regression procedures which will be used to produce production rate predictions require a relational data organization.

Data Base Management Systems

The Data Base Management System is the software used to store and access the data. Access to the data base may be made directly through the DBMS or through an application program. In general, all data storage, retrieval and manipulation is controlled by the DBMS. Figure 8 presents a schematic illustration of the function of a DBMS.

Observational data records are entered into the data base usually through menu driven DBMS software. The production rate prediction model accesses the observational data through the DBMS. Production rate analysis and prediction data generated by the model are also stored in the data base. Each organization is likely to custom tailor the distribution of production rate information reports on the basis of its particular needs.

Many data base management systems are available on the commercial market. These software packages can be provided for the microcomputer, mini computer and

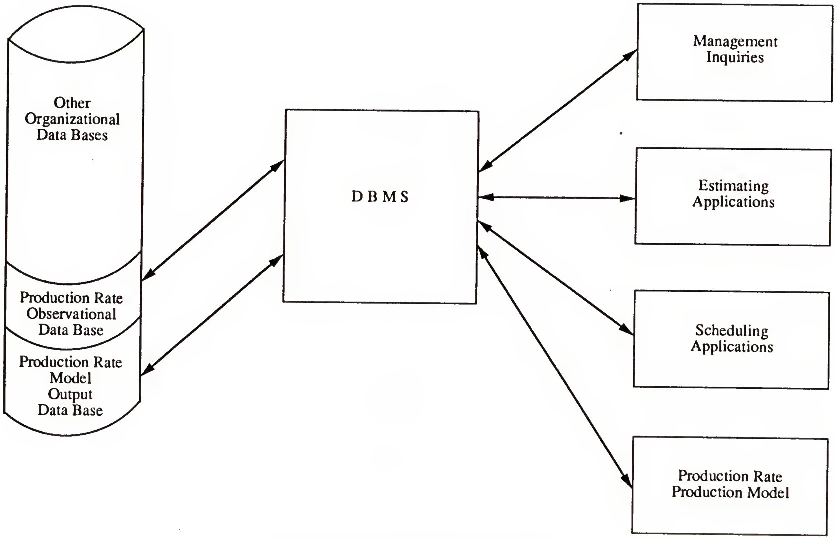

Figure 8. – Schematic Illustration of the DBMS

mainframe environments. Hardware is usually not a prime consideration. However, since the DBMS and production rate prediction model may not be part of the same application package, software compatibility is essential.

Use of a central data base has several advantages. The various functional users of the data have efficient access to the core of organizational information. Centralization also prevents redundancy of data storage. Information is input and stored only once.

In spite of these advantages, many organizations in the construction industry do not use a centralized DBMS. Data storage and management is frequently organized by function. Each functional segment operates with its own application software and data storage. The resulting organizational arrangement can be described as a matrix. Figure 9 presents a schematic illustration of a typical matrix data storage organization.

The production rate prediction model can be designed to operate in a matrix type organizational environment. In this case, the production rate data and modeling application software are operated as a separate function within the organization.

Summary

The storage and management of production rate data are important to the efficient use of the production rate prediction model. Large quantities of observational data

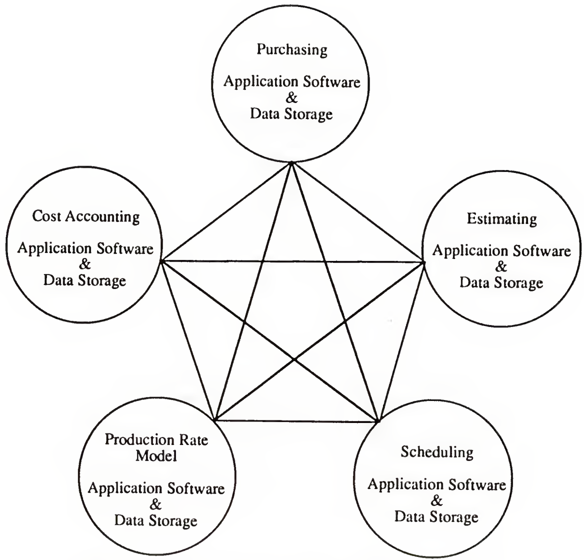

Figure 9. – Schematic Illustration of a Matrix Data Base Arrangement

must be stored and accessed. A relational data storage system is best suited for product rate data. Each record in the data base consists of a single observation of production.

A centralized data storage arrangement which is managed by DBMS software appears to be most desirable. However, the production rate modeling system can operate as a separate functional unit.

CHAPTER 5

MODEL DEVELOPMENT

Introduction

Modeling is a technique for defining and explaining relationships among various sets of variables. Usually, there will exist a dependent variable of interest which the model attempts to explain in terms of independent variables. In the case of construction production rates, we want to explain production rates as a function of various influencing factors. Additionally, we would like to predict future production rates, given a specific set of influencing factors.

The previous chapters have included a discussion of data collection and data base management considerations. The next step in the design of the production rate modeling system is the development of the model. Details of the statistical tools used in model design will be covered in the next chapters. There are, however, several general modeling concepts which should be explained prior to undertaking formal statistical procedures.

This chapter will present the basics of modeling theory and discuss various approaches to model construction. In addition, a few of the most common pitfalls will be noted.

Modeling Theory

Modeling is an attempt to describe an actual process in terms of input and outcome. Figure 10 illustrates a typical process. There will exist certain input variable or conditions and there will exist an outcome or result. Usually, we are interested specifically in the outcome. Therefore, modeling begins with an examination of the process to be modeled. This examination will produce three fundamental elements (Box, Hunter and Hunter 1978):

1. Indentification of the input variables
2. Indentification of the resultant variables
3. Formulation of the relationship among variables.

Often many possible models might be formulated. However, the researcher will choose trial models which are considered to be plausible based upon knowledge of the process of interest.

Deterministic and Probablistic Models

Deterministic models hypothesize an exact relationship between variables. Many examples of deterministic models exist in science and engineering. Ohms law is a classic example of a deterministic model. The relationship between current, voltage and resistance is exactly defined by the model.

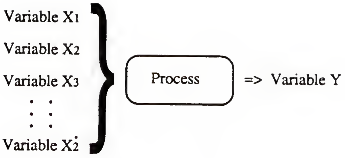

Figure 10. – Illustration of a Process to be Modelled

However, many real life processes can not be adequately modeled by deterministic models. We find that there will often exist a random error component. Therefore, a probablistic model will provide the best description of actual processes. In practice, the probablistic model consists of a deterministic component and a probablistic component. A typical probablistic model might be described as follows:

Outcome = Determinist Component + Probablistic component

The probablistic component of the model accounts for random errors which cause variation in the expected outcome. Also, in most cases, we realize that there may be unknown variables effecting the outcome. The variation causes by unidentified variables is included in the probablistic component.

Causation and Correlation

The distinction between causation and correlation is absolutely necessary. Correlation between variables can be used for predictions. However, correlation provides little information about the process. If we wish to optimize or change the process, we need to be concerned with causation.

Box and Hunter prodive a very good example of the difference between correlation and causation (Box and Hunter 1978). This example concerns the population statistics for Oldenburg, a European town famous for the storks which nest on the roofs of the houses. Scientific observations over a seven year period clearly showed a correlation between the

population of the town and the number of storks. As the number of storks increase so did the number of babies. Correlation clearly existed. However, it is unlikely that the increase in storks caused the increase in babies.

In fact, we often find that two variables, X and Y, are correlated because of their direct relationship with a third variable, Z. Knowing only X and Y, we can make predictions about the change in one with respect to the other. However, we can not identify the cause behind the relationship unless we identify the third variable.

In the Oldenburg example, the third variable is obviously time. Both the number of storks and babies were directly related to the passage of time over the seven year period.

Modeling Procedure

Modeling is an iterative process. First, a preliminary model is hypothesized based upon examination of the process. The model is then tested for adequacy. Modifications are made and the revise model is tested once more. The procedure is rather continuous. Figure 11 presents a schematic illustration of the modeling procedure.

The objective or goal of the model should be stated clearly at the start of the process. Each iteration of the modeling procedure should bring the model closer to the objective. If the objective is to make predictions about a dependent variable, then correlation is the central issue.

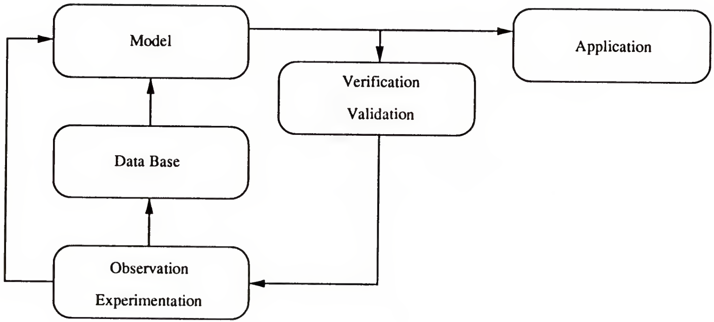

Figure 11. – Schematic Diagram of the Modeling Process

Variables may be included in the model on the basis of their correlation with the dependent variable.

If on the other hand, we are primarily interested in producing a model which reflects the actual process, then causation is the determining criteria. A model will be developed on the basis of how well it reflects the underlying relationships whether or not the predictive precision is optimized.

Another consideration in model development is that independent variables are sometimes not independent. That is, they are related to each other. Using independent variables which are correlated will cause problems with model precision. Therefore, model formulation should attempt to avoid the use of highly correlated independent variables.

Summary

The modeling process involves recognition of the various factors or variables which are involved. Based upon an examination of the experimental data and knowledge about the process, an attempt is made to describe the process in terms of the identified factors. The trial model is tested for adequacy and revisions are made until the model is judged successful.

Care must be taken to avoid non-independent variables. Also, the distinction between causation and correlation should be clearly understood.

CHAPTER 6

EXPLORATORY DATA ANALYSIS

Introduction

Exploratory Data Analysis (EDA) is a relatively new area of applied statistical analysis. John Tukey's book in 1977, Exploratory Data Analysis, presented the first comprehensive treatment of the subject (Velleman and Hoaglin 1981). The objective of EDA is to improve the efficiency of the research process. EDA procedures allow the researcher to detect features in the data which may be unnoticed in traditional analytical techniques. EDA is particularly useful in model development by visually revealing the behavior of the data.

In general, EDA procedures concentrate on the following three analytical techniques:

1. Visual Displays - revealing the nature of the data.
2. Residuals - analysis of the lack of fit between the model and the data.
3. Resistance - protecting the model from the influence of outliers.

This chapter will present several EDA techniques which are particularly appropriate for evaluating construction production rate data. A thorough examination of the data coupled with a complete understanding of the underlying process provides the most successful approach to model development. Correctly applied EDA will assist in matching the mathematical model to the true process.

Stem and Leaf Plots

Stem and leaf plotting is a technique for visually displaying the data. Data points are laid out according to certain stem and leaf rules to form a picture of what the batch of data looks like.

Examination of the data display can provide important insight into the overall data pattern. The stem and leaf visual display may provide the following information (Velleman and Hoaglin 1981):

1. What the range of data values are.
2. Where most of the values are concentrated.
3. What the shape of the data distribution is.
4. Whether there are gaps where no values exist.
5. Whether or not there are outlying values.

This preliminary information can greatly assist the researcher in getting acquainted with the research data.

Stem and leaf plots are constructed by ordering the data values in accordance with their digits. Each value is split into leading digits called stems and trailing

digits called leafs. For example, a data value such as 63128 might be divided into stem and leafs as follows:

Stem	Leafs
63	1

Note that only the first digit of the trailing digits is used to represent the leaf portion. The choice of where to split the data value depends upon the range and distribution of the values. The idea is to plot the data points over a range which best depicts the behavior of the data.

For example, Figure 12 is a stem and leaf display for the data given in Table 6. The data consist of construction production rate observations of structural steel erection. The values represent daily production expressed as a ratio of expected production. The research data were collected from three commercial building project sites in Pennsylvania.

In Figure 12, the stem and leaf display has been constructed by using the first digit of the value as the stem. The first digit of the trailing digits then becomes the leaf. Within the range of data values, all possible stems are listed whether or not values actually occurred. Each value is then added to the display by adding its leaf to the appropriate stem.

We can see from stem and leaf plot that the concentration of data values appears at the 0 and 1 stems. Sometimes it is helpful to spread out the plot in order to obtain a wider display of the data. This can be done by

Table 6. - Production Rate Data for Steel Errection

Observation No.	Calendar Date	Activity	Performance Ratio	Temperature (°F)	Relative Humidity (%)
1	February 05	Steel	0.79	41.3	71
2	February 06	Steel	0.65	33.1	59
3	February 10	Steel	0.80	27.9	67
4	February 11	Steel	1.95	28.8	73
5	February 12	Steel	0.64	28.5	59
6	February 13	Steel	1.01	24.1	64
7	February 14	Steel	1.33	17.0	60
8	February 20	Steel	0.94	37.0	75
9	February 24	Steel	0.77	32.3	56
10	February 25	Steel	1.49	26.6	40
11	February 26	Steel	0.62	30.2	54
12	February 27	Steel	1.94	27.3	59
13	February 28	Steel	0.81	29.5	54
14	March 03	Steel	1.18	37.7	44
15	March 04	Steel	5.13	20.3	85
16	March 05	Steel	0.62	38.5	70
17	March 06	Stcel	1.34	30.8	80
18	March 07	Steel	4.30	11.6	47
19	March 10	Steel	2.40	52.0	40
20	March 11	Steel	3.25	36.4	63
21	March 12	Steel	3.30	36.5	60
22	March 13	Steel	1.56	37.0	81
23	March 14	Steel	1.55	40.8	83
24	March 17	Steel	2.27	37.3	58
25	March 18	Steel	1.56	45.0	49

Source: (Thomas and Yiakoumis; 1988) Reprinted with permission of publisher

Stems	Leaves
0	7 6 8 6 9 6 8 6
1	9 0 3 7 4 9 1 3 5 5 5
2	4 2
3	2 3
4	3
5	1

Figure 12. – Stem and Leaf Display of the Data from Table 6.

using multiple lines per stem. Each stem value is listed on two consecutive lines. Leaf values from 0 to 4 are posted to the first line. Leaf values from 5 to 9 are posted to the second line.

Figure 13 is a stem and leaf display of the same data used in Figure 12, however, multiple lines have been used. In this case, the display reveals more detail concerning the data distribution.

Figure 13 also contains a depth value which has been added to the left of the stem column. The depth number represents the number of values which lie either on that line or on a line closer to the nearest end of the data distribution. Usually, the middle line shows, as a depth value, the number of values listed on that line in parentheses. If the plot contains an even number of data lines, no middle line exists. In this case, the depth values on either side of the middle are listed in the usual manner.

The stem and leaf plots closely resemble another commonly used display technique called the frequency histogram. In the histogram, data values are represented by equal spaces on bars. The bars are plotted together in a graph which depicts the shape of the data distribution.

Histograms do not provide information about the individual data value. The stem and leaf plot uses the actual data values to construct the display. Therefore, the researcher has immediate access to the data.

Unit = 1.0

1 9 represents 1.9

	0	
9	0	7 6 8 6 9 7 6 8 6
14	1	0 3 4 1 3
19	1	9 9 5 5 5
21	2	4 2
	2	
4	3	2 3
	3	
2	4	3
	4	
1	5	1
	5	

Figure 13. – Stem and Leaf Display of the Data from Table 6 Using Multiple Lines.

Nevertheless, histograms are useful when the data batch contains a large number of observations. When, for instance, several hundred values are involved, the stem and leaf display provides a level of detail which would be difficult to analyze. The histograms are a better choice for displaying large data samples.

For the data given in Table 6, Exploratory Data Analysis using stem and leaf displays provides a great deal of useful information about the data. We see that the data values are generally concentrated in the range of 0.5 to 1.9, which includes 19 of the 25 observations. The range of 0.5 to 0.9 contains the largest number of values. The data is skewed to the right with the tail stretching to a high value of 5.1. The higher values are more spread out than the lower values.

Boxplots

The boxplot is another important EDA tool. The boxplot is a graphical technique which is particularly useful in examining the tails of the data distribution. Often it is the data values which are spread out significantly from the center which are of most interest. We would like to understand what circumstances and what factors resulted in the large variance from the mean.

The concept of depth is important to the development of the boxplot technique. If the data values are arranged in an ordered sort from lowest to highest, the depth of

each data value will be how far it is from the closest end of the batch. The central most values have the greatest depths. The lowest depths occur at the extremes.

The boxplot graph is constructed after determining certain key data characteristics. These descriptive characteristics are listed as follows:

Median - If we are dealing with a data batch containing an odd number of data values, there will exist one value with the greatest depth. If the batch contains n values, then one half of the n-1 values will be less than median and one half will be greater than the median.
If the batch contains an even number of observations, then the median is defined by convention as the average of the two middle points.

Hinges - The median divides the data batch into two halves. The hinge also splits each of the halves.

Hinge Spread - The difference between the upper and lower hinge values is the hinge spread.

Inner Fences - The inner fence is defined as the lower hinge - (1.5 x Hinge Spread)

and the upper hinge + (1.5 x Hinge Spread)

Outer Fence - The outer fence is defined as the lower hinge - (3.0 x Hinge Spread) and the upper hinge + (3.0 x Hinge Spread)

The fences are used to distinguish outlying data values.

Construction of the boxplot begins by building a box from hinge to hinge. A line is placed across the box to indicate the position of the median. A dashed line, or whisker, is now drawn from each hinge out to the inner fence. Values outside the fence are shown individually.

Figure 14 presents a boxplot of the data given in Table 6. Only a brief examination of the boxplot display provides useful information about the data batch. We can see that the median value is around 1.50 and that the hinge spread is about 1.10. The data is not symmetrically distributed. The median occurs in the upper half of the box. The upper whisker is much longer than the lower whisker. The two values outside the upper fence are clearly distant from the main data grouping. These high values probably deserve additional investigation to determine what factors may have resulted in the increased production.

Many of the commercially available statistical analysis computer software programs can provide computer generated EDA outputs.

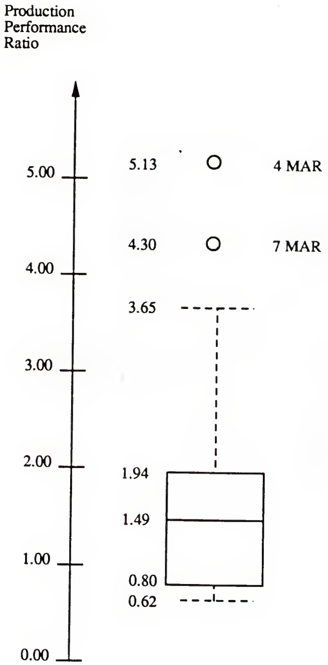

Figure 14. – Boxplot for the Production Rate Data Given in Table 6

Summary

The model development process begins with a thorough analysis of the observational data and hopefully an understanding of the underlying process. EDA provides simple analytical tools for learning the nature of the data. This preliminary examination of the data provides guidance for designing additional data collection methods and suggest relationships to be accounted for in the model development.

Stem and leaf plots provide a visual display of the data with the advantage of using the data values in the display. Boxplots also provide a graphical display of the data and are particularly useful in examining outlying values.

EDA techniques generally should be a prerequisite to the application of more advanced statistical procedures. Chapter 7 will cover additional statistical procedures which are applicable to analysis and modeling of construction production rate data.

CHAPTER 7

STATISTICAL ANALYSIS PROCEDURES

Introduction

Inferential statistics generally begins with a population of interest. In our case, the population consists of all production rates experienced by an organization within an established period of time. We would like to be able to make certain inferences about the general population using only a sample of the population. Our sample of the population consist of production rate observations collected from field sampling. Statistics furnishes the tools for establishing inferences about the population based upon samples.

Additionally, statistics provides a technique for developing a mathematical model representing the process of interest. In this case, we want to describe the dependent variable, production rate, as a function of the various productivity, influencing factors. Once established, this mathematical model can be used to predict future production rates, given the influencing factors.

This chapter will introduce basic statistical concepts which will provide the foundation for developing the prediction model. The least-squares method of matching the general linear model to the data will be presented. The fundamental assumptions upon which the statistics are based will be given and related to construction production rate data. The specific steps for applying the regression technique will be given. Also, a discussion of pitfalls to be avoided will be included.

The purpose of this chapter is not the development of complete statistical theory. Rather, the purpose is to present statistical tools which are important to the model building process and to explain relevant theoretical assumptions.

The General Linear Model

Application of statistical analysis to the problem of matching a mathematical model to research data begins with a single general model. This single model, called the general linear model, can be expressed as follows (Ott 1988):

$$Y = \beta_o + \beta_1 X_1 = \beta_2 X_2 \ldots + \beta_k X_k + \epsilon$$

In this model, the dependent variable is represented by Y. The S's represent the independent variables. The β's are parameter estimates of the independent variables. The random error associated with the model is represented by ϵ.

The general linear model describes as an equation the relationship between the dependent variable of interest and other variables which affect the value of the dependent variable. Since this is a probablistic model, a random error term is also included. This random error term accounts for all unexplained and unpredictable factors which may influence the value of the dependent variable. However, we will assume that the average value of ϵ for a given value of X is equal to 0.

It is also important to understand that the general linear model can include both quantitative and qualitative independent variables. Dummy variables are formed by representing the X's as 1 and 0 are used to incorporate qualitative independent variables into the model.

Because we have assumed that the mean value of the random error term is equal to 0 and the values for β are constants, the expected value for Y or mean value of Y becomes an equation which describes a line. Plotting the expected value of Y, E(Y), produces a line which traverses the plotted actual values of Y. Points which lie on the line represent the expected value of Y at given values of the independent variables. If our linear model is the simple equation

$$Y = \beta_o + \beta_1 X_1 + \epsilon$$

then the expected value of Y would be equal to $\beta_o + \beta_1 X_1$. Figure 15 presents an illustration of this concept. The actual observed values of the dependent variable have been

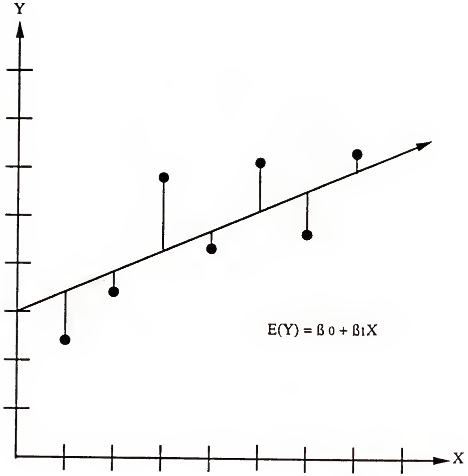

Figure 15. – Example of Plotting the Linear Model Equation

plotted against observed values of the single independent variable. The predicted value of Y has also been plotted as the equation $Y = \beta_o + \beta_1 X_1$. For each actual value of Y, there exists some error or difference between the actual value and the predicted value. In general, we would like to obtain an equation which best fits the data, and reduced the total amount of error between the model and the data.

Regression and Inference

Least Squares Method

The statistical technique used to determine the model which best fits the data is called the least squares method. The predicted value of Y is represented by Yh. For each Yh there exists a difference or prediction error between Yh and the actual value of Y. This prediction error, Y - Yh, is called the residual. The least squares method develops a prediction equation which minimizes the sum of the squares of the prediction errors.

Therefore, we are seeking estimates of the β values which result in a minimum $\Sigma(Y - Yh)^2$. Using calculus, we find that the following relationships exist (Ott 1988):

$$\beta h_1 = \frac{Sxy}{Sxx} \text{ and } \beta h_o = Y - \beta h_1 x$$

where

$$Sxx = \Sigma\ (x - \bar{x})^2 = \Sigma\ x^2 - \frac{(\Sigma x)^2}{n}$$

$$Sxy = \Sigma (x - \bar{x}) (y - \bar{y}) = \Sigma xy - \frac{(\Sigma x) (\Sigma y)}{n}$$

and n = number of values

It is common in statistical analysis to view this relationship in terms of the variability of the process. In other words, variance can be described as follows

$$\Sigma (y - \bar{y})^2 = \Sigma (yh - \bar{y})^2 + \Sigma (y - yh)^2$$

or

$$\text{total variability} = \text{variability explained by model} + \text{unexplained variability}$$

The least squares approach can also be applied to the solution of models which include multiple variables and quadratic terms. The principle is the same. The solution involves the simultaneous resolution of multiple equations. Calculations are substantially more complex and warrant the use of computers.

<u>Confidence and Prediction Intervals</u>

Recall that one of our main objectives was to be able to make predictions of future production rates. It might be useful if we could also determine the accuracy of our predictions in advance. Statistics provides a technique for establishing the accuracy of our predictions.

When we are trying to estimate the mean value of Y

$$E(Y) = \beta_o + \beta_1 X_{12}$$

where X_2 is the value of X_1 at the point of interest. We use estimates of β_o and β_1 to estimate Y as follows

$$Y = \beta_o + \beta_1 X_{12}$$

so the source of error for our estimate of Y is β_o and β_1.

The variance for the estimate of E(Y) can be expressed as follows (Scheaffer and McClave 1986, 373):

$$\sigma^2 = E\ \{[Yh - E\ (Y)\ ]^2\} = \sigma^2\ [\ \frac{1}{n} + \frac{(X_p - x)^2}{SSxx}\ ]$$

where σ^2 = variance of Y

$Yh^{\cdot}$ = predicted value of Y

E(Y) = expected value of Y

n = number of values

X_p = value of a particular x

$\bar{X}$ = mean value of X

$SSxx = \Sigma\ (x - \bar{x})^2$

Therefore, the confidence interval for the estimate value of Y is expressed by the following equation (Ott 1988, 356)

$$Y \pm t\alpha/_2\ S_E \sqrt{\frac{1}{} + \frac{(x - \bar{x})^2}{Sxx}}$$

where $t\alpha/_2$ = t test statistic at $\alpha/_2$

$\alpha/_2$ = selected confidence interval probability.

n = number of values

S_E = sample variance

$Sxx = \Sigma\ (\bar{x} - x)^2$

This interval defines our confidence in the predictions for the mean value of Y. For instance, if we had selected an α of .05, we would expect the actual mean value of Y to fall within this interval 95% of the time.

Now, consider the case where we are interested in estimating a particular value of Y.

$$Y_2 = \beta_o + \beta_2 X_2 + \epsilon_2$$

Note that the equation now includes the error term. The source of error for prediction of a particular value are β_o and β_2 and ϵ_2. Therefore, the variance now includes an additional term and is expressed as follows (Scheaffer and McClave 1986, 373):

$$\sigma^2(Y_p - Yh) = E\,[\,(Y - Y_p)^2\,] = \sigma 2 + \sigma^2 Y$$

$$= \sigma_2 \left[1 + \frac{1}{n} + \frac{(X_p - \bar{X})^2}{SS_{xx}} \right]$$

The confidence interval for predicting a particular value of Y is now defined by the following equation (Ott 1988, 358):

$$Y \pm t\alpha/_2\, S_E \quad \left[1 + \frac{1}{n} + \frac{(x - \bar{x})^2}{Sxx} \right]$$

It should be noted at this point that the confidence interval for the prediction of the mean value of Y is narrower than the interval for the prediction of a particular value of Y. Figure 16 illustrates this concept. In the figure, the simple equation

$$E(Y) = \beta_o + \beta_1 X_1 + \epsilon_1$$

has been plotted. Both the mean value and particular value confidence intervals also have been plotted.

Obviously, the usefulness of the production rate prediction model depends largely upon the accuracy of the

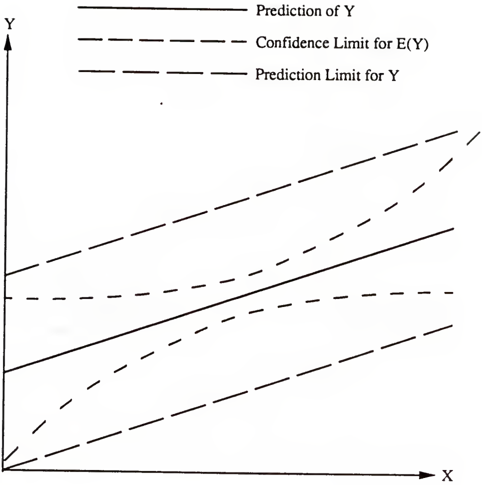

Figure 16. – Confidence and Prediction Intervals for E(Y) and (Y)

predictions. Statistical confidence intervals provide an important measure of the accuracy of the production rate model.

From the equations for the confidence and prediction intervals, several general observations may be made. Specifically these points are as follows:

1. The width of the interval will decrease as n increases. Including more observations improves the precision of the estimates.

2. The quantity $(x - \bar{x})^2$ is smaller as we approach the mean value of x. Therefore, the estimate precision is better towards the center of the x region.
3. $Sxx = \Sigma (x - \bar{x})^2$ will increase as the spread of values for x increases. Therefore, within limits, the estimate precision is improved by increasing the ranges of X values.

These observations should be considered when designing the field sampling system.

Fundamental Assumptions

The general linear model and our solution to the model using the least-squares method are based upon specific fundamental assumptions concerning the population of interest. The validity and precision of predictions from the model are dependent upon whether or not the

initial assumptions are true. Therefore, it is important to recognize and understand what these assumptions are.

Four initial assumptions concerning variance make up the foundation of our approach to the method of least squares. These assumptions are listed as follows:

1. The random error term ϵ is assumed to have a normal probability distribution.
2. The random error term ϵ is assumed to have a mean equal to 0.
3. The random error term ϵ is assumed to be constant over all values of X.
4. The random error term ϵ is assumed to be independent among different observations.

The validity of these assumptions generally is tested most readily by examining plots of the residuals plotted against the variables used in the model. The least squares method is fairly robust with regard to the assumption of normality. Useful results can be obtained even using skewed populations.

However, the assumptions concerning ϵ having a mean value of 0 and being homogeneous for all values of X, are critical. In some cases, transformations of the input data may improve the validity of the assumptions. A great deal of statistical research has been done in this area and several advanced techniques have been developed (Draper and Smith, 1981).

Multiple Regression Steps

Step 1: Variable Selection

Choosing potential variables which may be reasonably expected to affect the dependent variable is an important part of the regression procedure. The final results of the model will depend to a great extent upon the validity of the selected variables. In this step of the regression process; it is absolutely essential to obtain the expertise of persons experienced in the working of the process to be modeled. This concept is made by (Ott 1988, 541) as follows:

> The input of a person knowledgeable in the subject matter field is a valuable source of advice on reasonable (independent) variables that could influence the response (dependent variable) of interest.

For example, in highway construction, experienced field personnel, such as project superintendents and field engineers, are likely to provide the most accurate information concerning influencing factors for specific work activities. Skillful questioning by the researcher can produce a list of potential influencing factors for each activity of interest. The idea is to put together a list of variables which are related to the dependent variable (production rate) and not to one another.

When adequate computer resources are available,trial regressions should commence with all possible variables included in the model. The result of each model is

evaluated statistically. The model providing the most desirable result is selected.

There are, however, several different statistical criteria for evaluating regression models. One criterion is the R^2 statistic. The coefficient of determination, R^2, is defined as the portion of variability of the independent variable which is explained by the model. R^2 is calculated as follows (Ott 1988, 490):

$$R_y^2 = \frac{Syy - SSE}{Syy}$$

where $$Syy = \Sigma Y_2{}^2 - \frac{(\Sigma Y_2)2}{n}$$

and $$SSE = \Sigma\ (Y_2 - Y_2)^2$$

One of the best criterion for model selection is the Cp statistic (Mallows 1973). The Cp statistic has been shown to provide a balance of both overfitting and underfitting. The Cp method gives a model with the best estimate precision. The Cp statistic is defined as follows (Ott 1988, 545):

$$Cp = \frac{SSEp}{S_\epsilon^2 - (n - 2p)}$$

where SSEp is the sum of squares for the error model with p parameters included

and S_ϵ is the mean square error from the regression equation with the largest number of independent variables.

The Cp theory states that the best model is obtained at the point where the value of Cp approaches P. Figure

17 provides a plot of Cp vs P for a typical model selection procedure. The best model is the model where Cp first approaches the value of P.

Step 2: Refining the Model

The initial model formula will likely be a lower order linear equation of the form $Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta 3 x_3$. Some relationships between the dependent variable and the parameters can best be described by the addition of a quadratic term to the equation. An examination of a plot of the residuals verses the parameter values will indicate whether a quadratic term is needed. A plot of residuals verses X2 which shows a curved pattern reveals the need

for a quadratic term of the form $\beta_2 X_2{}^2$.

Much of the model refinement amounts to a trial and error process guided by knowledge of the underlying process and residual analysis.

Step 3: Verifying Statistical Assumptions

After identifying the independent variables and formulating the model equation, the next step is to verify the original statistical assumptions. These original assumptions, which were declared previously in this chapter, concern the variance of the error term. Verification of assumptions may be directly confirmed by examination of residual plots.

If step 2 has been successfully completed, the assumption of zero expectation of the error term should

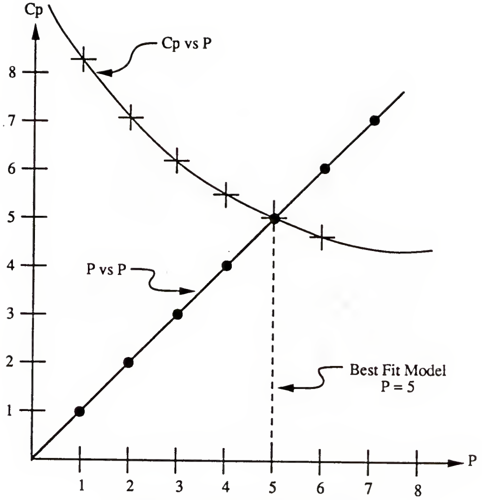

Figure 17. – Example Plot of Cp Statistic

prove correct. If mean value of the error term is not zero, the model does not adequately represent the process being modeled.

The assumption of constant variance can be checked by examining a plot of residuals verses the predicted value of the dependent variables. The assumption is correct if the residual plot shows a random scattering of point for all values of variables. If, however, the range of residuals in much different at different levels of the X variable, heterogeneous variance is suggested.

Verification of assumption number three, that the distribution of the value of the error term is normally distributed, is done by plotting a frequency histogram of the residual values. Any skewedness will be detected in the histogram plot.

The final assumption is that the error terms are independent from one observation to another. If the time sequence of observations is known, a plot of the residuals verses time will show if adjacent residual in time appear to be similar. Additionally, the Durbin-Watson formal test may be performed to check for serial correlation (Durbin and Watson 1951).

The consequences of non-validity of assumptions depend upon which assumption is violated. The least squares method is rather robust with regard to the assumption of normality. Useful estimates can be obtained even with skewed distributions.

However, the assumption of constant variance is more critical. A heterogeneous variance will effect the accuracy of the least squares estimates. In other words, the precision of the model is reduced. Also, the width of the prediction interval for individual values of Y may be inconsistent. The width of the interval may depend upon the range of variance at the prediction point (Ott 1988).

Transforming the input data into another format, such as a logarithmic value, may eliminate heterogeneous variance problems.

Summary

Statistical tools are an integral part of the model development system. Using the least squares method, a regression equation can be developed from the sample data. Statistics also allows for the development of confidence and prediction intervals for model estimates of the dependent variable.

The statistical regression procedure can be described in three steps:

step 1: Variable Selection

step 2: Refining the Model

step 3: Verification of Statistical Assumptions

Figure 18 presents a flow diagram of the regression procedure.

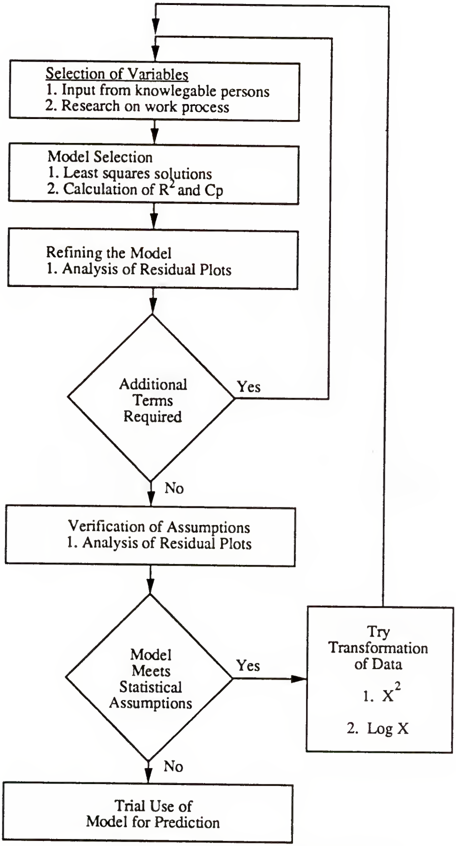

Figure 18. – Schematic Flow Chart of Regression Process

In the next chapter, these statistical methods will be applied to developing a production rate model for highway construction.

CHAPTER 8

MODEL CONSTRUCTION: CASE HISTORY

Introduction

Previous chapters have presented a review of various data collection and theoretical modeling techniques. This previous information was compiled as background knowledge for the actual problem of modeling construction production rates.

This chapter will cover the experimental application of the production rate influencing factor theory to the development of an actual predictive model. Using the techniques previously discussed, production rate models are developed for several highway construction activities. The research methodology and modeling procedure will be presented with a critical evaluation of the results.

Objective

The purpose of this research was to determine the validity of the theoretical factorial model for construction production rates. The objective of the

models was to provide more precise predictions of future production rates.

Research Methodology

Research Procedure

This investigation was made in connection with a study undertaken by the Department of Civil Engineering, University of Florida, at the request of the Florida Department of Transportation (FDOT), (Herbsman and Ellis 1988). The purpose of the research study was to examine production rates currently used by the Florida Department of Transportation and to make recommendations for revisions where appropriate.

The current investigation involved four distinct phases which are listed as follows:

1. Preliminary selection of Variables
2. Collection of Data
3. Model Development
4. Model Testing.

Each of these steps will be covered separately in the following sections.

Preliminary Selection of Variables

The first phase of the study consisted of developing a preliminary list of Construction Production Rate Influencing Factors. This identification of CPIF's was required prior to designing the data collection system.

It is obviously necessary to target variables of interest before undertaking data collection.

Information about potential influencing factors was obtained from two primary sources. First, structured interviews were conducted with knowledgeable persons working in the highway construction industry. These people included contractor superintendents and FDOT field engineers. Secondly, direct observations were made of the actual work activities by the author.

Five construction activities were selected as being representative of the type of work included on a typical highway construction project. These five activities are:

1. Clearing and Grubbing
2. Excavation
3. Base Installation
4. Asphalt Pavement
5. Storm Drainage

Based upon the preliminary investigations, a list of factors was developed for each of these activities. This list includes a number of project and environmental items which are applicable to each activity. In addition, each of the individual activities also was assigned activity factors applicable only to that activity.

Figure 19 presents the list of general factors with explanations. Figure 20 presents the activity related factors chosen.

Factor	Explanation	
Total	Total amount of activity work in project	
Price	Total contract price for project	
Type of Project	General category of the project	: New Construction Recontstruction Bridge Intersection Improvement Signalization
Local Condition	Site Conditions	: Urban Rural Limited Access
Traffic Conditions	Traffic volume on roadway	: Light Medium Heavy

Figure 19. – List of General Factors

Activity	Factor	Explanation	
Clearing and Grubbing	Level of Clearing	Degree of Clearing Required	: Light – Brush Medium – Brush and Small Trees Heavy – Large Trees and Brush
Excavation	Type of Excavation	Type of Excavation	: Lateral Ditch Regular Subsoil
	Type of Material	Type of Material to be excavated	: Sand Rock Muck
Base	Type of Material	Type of Material to be Installed	: Limerock Shell Sand Clay Soil Cement Asphalt
Asphalt	Small Areas	Installation of Small Areas	ie:Intersections, Drives ect.
Storm Drains	Depth	Depth of Installation	
	Diameter	Diameter of Pipe	

Figure 20. – List of Activity Factors

It should be noted that this particular model has been designed to be used by an owner such as the FDOT. Therefore, organizational factors related to the contractor were not included in the model. Prior to bid award, the owner has no way of knowing who the contractor will be. Consequently, contractor related factors are of little use in pre-bid predictions of production rates.

Collection of Data

After variable selection, a data collection system was developed. Observations of production rates and factorial values were obtained from FDOT construction projects. Projects were selected on a stratified random sample basis. This means that an conscious attempt was made to obtain observations for each work activity of interest. However, within the category projects were selected randomly.

Observations were made by FDOT field engineers assigned to the projects. A data collection form was designed for recording and reporting the field observations. The final design of the form required numerous discussions with FDOT field personnel to insure that the instructions and wording would be clear to the persons recording the data. Copies of the data collection forms are provided as Appendix A.

A total of 60 projects were observed. Table 7 presents a description of the sample data base.

Table 7. - Description of Data Base

Work Activity	Number of Observations	Number of Variables Per Observation
Clearing and Grubbing	96	18
Excavation	113	21
Base Installation	151	18
Asphalt Pavement	188	16
Storm Drains	97	17

Because of the size of these data sets, they have been included as Appendix B rather than included in the text.

Originally, the raw data were entered into a spread sheet data base. Later, the spread sheet data was translated and reformatted as a SAS data set. This transfer from one software system to another required a considerable amount of labor. Inputing directly into the SAS system is recommended for future research.

The data sets enclosed in the Appendix B are copies of the SAS data sets.

The statistical analysis procedures used for regression require quantitative variables. Therefore, the qualitative variables have been transformed into binary form.

For example, consider the following observations for the Traffic variable.

Obs	Traffic
1	L
2	M
3	H
4	H
5	L

When transformed the data set has the following form:

Obs	Traffic-L	Traffic-M	Traffic-H
1	1	0	0
2	0	1	0
3	0	0	1
4	0	0	1
5	1	0	0

Binary form allows for analysis of qualitative factors.

Computer Software and Hardware

Raw data were originally entered into a LOTUS spread sheet data base. Subsequently, the LOTUS data were transferred to a SAS system. Data base management and manipulation was performed using Base SAS software for personal computers. Statistical analysis was performed using SAS/STAT software for personal computers. A copy of all source codes used is enclosed as Appendix D.

The computer hardware consisted of an IBM OS/2 Model/50. Data handling and statistical routines were reasonable efficient in the PC environment. Statistical processing of typical data sets was performed in less than 20 minutes.

The SAS system is available for both mini and main frame environments. Depending upon the expected size of the data base, some users might consider moving up from the PC environment.

Model Development

Model development was accomplished with the aid of the SAS Proc Reg procedure which performs advanced regression procedures. This software procedure is a least squares regression technique with many diagnostic options.

Preliminary model selection was made on the basis of Mallow's Cp statistic. A regression of all possible models was run and the Cp statistic was computed for each model. The selected model was the model where Cp was approximately equal to the number of parameters in the model.

Complete copies of all regression procedures computer output are enclosed as Appendix C.

An example of the Cp-P selection criteria is presented in Table 8, which includes the Cp statistic values for all trial models used for the Clearing and Grubbing activity.

The model selected for Clearing and Grubbing was Model Number 13 which resulted in a Cp of 13.06 and a P of 13. Recall that Mallow's theory defines the best fitted model as occurring when Cp is approximately equal to P.

The preliminary model selected for Clearing and Grubbing is presented in Figure 21.

The same selection procedure was carried out for each of the five activities.

Table 8. - Listing of Cp Values for Trial Models for Clearing and Grubbing

Model Number	Number of Parameters P	Mallows Cp	Coefficient of Determination R^2
1	1	48.75	0.156
2	2	41.09	0.212
3	3	1.56	0.465
4	4	1.15	0.470
5	5	1.85	0.478
6	6	1.28	0.493
7	7	3.08	0.494
8	8	4.91	0.495
9	9	6.59	0.497
10	10	8.29	0.499
11	11	9.57	0.503
12	12	11.16	0.505
13	13	13.06	0.506
14	14	15.00	0.506

Source	Sum of Squares	
Model	305.22	$F = 5.71$
Error	308.40	$R^2 = 0.497$
Total	613.63	$Cp = 13.00$
		$P = 13.00$

Variable	Parameter Estimate	F
Production Rate = Intercept	-1.56176250	0.54
Total Quantity	0.00000019	1.33
Reconstruction	0.76935595	0.79
Bridge	0.46724565	0.12
Intersection	1.26508184	0.97
New Construction	0.64066488	0.22
Rural	-1.26460744	1.75
Limited	1.32878210	0.45
Medium Traffic	-1.12675576	0.71
Heavy Traffic	0.08239762	0.00
Total Quantity^2	-0.00049047	20.15
Medium Clearing	1.05844360	1.17
Heavy Clearing	2.18553138	2.97

Figure 21.-Preliminary Model Selected for Clearing and Grubbing

The next step was to examine the residual plots of the preliminary models. The purpose of residual analysis is to verify the fundamental statistical assumptions. Analysis of the plot of the residuals versus the dependent variable and independent variables detected a problem with our assumption of homogeneous variance. Figure 22 is the residual plot of residual versus production rate for clearing and grubbing. Figure 22 clearly indicates an increase in variance as the dependent variable, production rate, increases.

Figures 23, 24, and 25 give the residual plots for the independent variables Total Quantity, Total Quantity^2, and Price respectively. Analysis of these plots also indicates heterogeneous variance to a lesser degree.

A logarithmic transformation of the data was performed as a trial remedy for the variance problems. This was accomplished by transforming the input data set values into their Log base e components. The form of the transformation was

Transformed Y = Log Y

Following transformation of the data, the model selection process was repeated using the transformed data. The model selection routine resulted in a new preliminary model which now included logarithmic variables. In general, the R^2 values were substantially improved. For example, the R^2 value for Clearing and Grubbing increased from 0.506 to a new value of 0.732. This improvement in

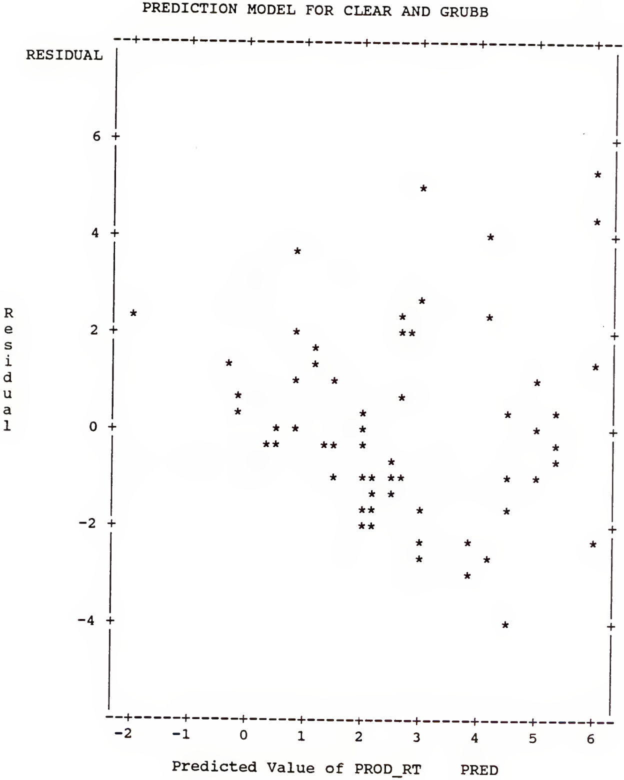

Figure 22.-Residual Plot of Production Rate Variable for Clear and Grubbing

PREDICTION MODEL FOR CLEAR AND GRUBB

Plot of YRESID*TOT_QTY. Symbol used is '*'.

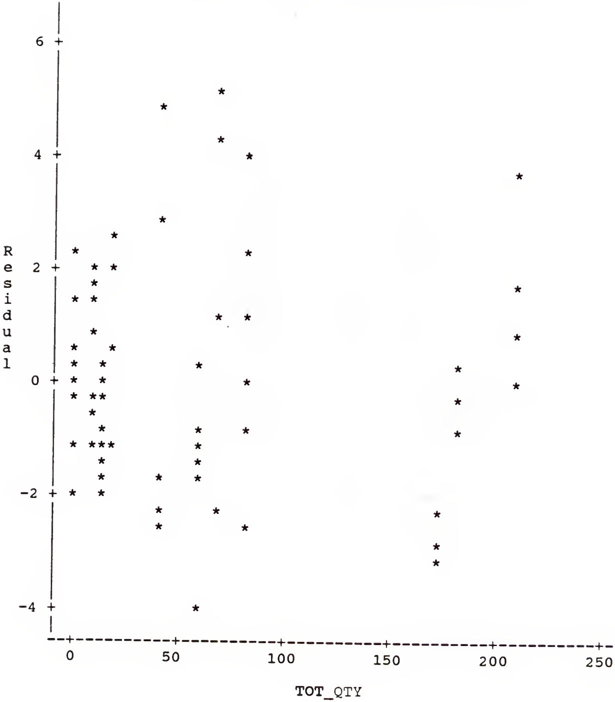

Figure 23.-Residual Plot of Total Quantity Variable for Clear and Grubbing

PREDICTION MODEL FOR CLEAR AND GRUBB

Plot of YRESID*TOT_QTY2. Symbol used is '*'.

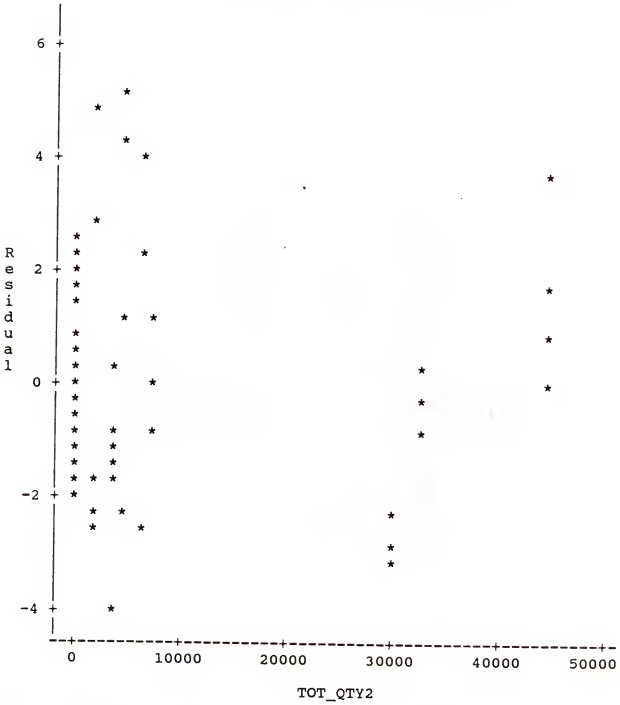

Figure 24.-Residual Plot of Total Quantity^2 Variable for Clear and Grubbing

PREDICTION MODEL FOR CLEAR AND GRUBB

Plot of YRESID*PRICE. Symbol used is '*'.

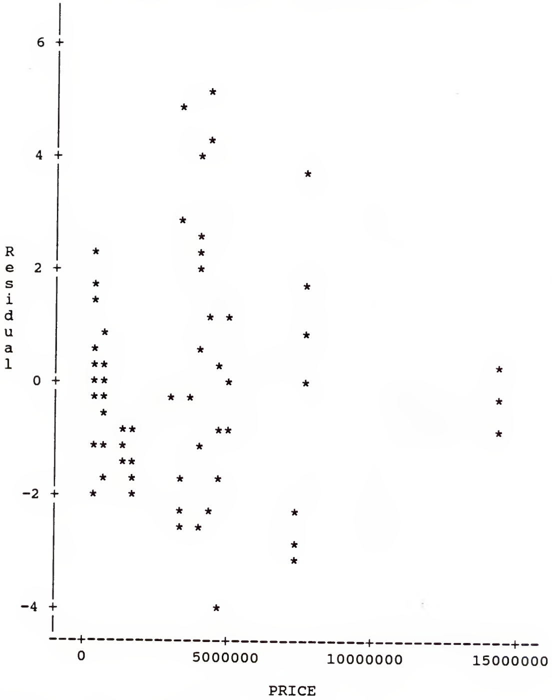

Figure 25.-Residual Plot of Price Variable for Clearing and Grubbing

R^2 is because the transformed input data now more closely matched the linear model upon which the regression procedure was based.

Analysis of the residual plots using the transformed data, indicated homogeneous variance across all variables. Figures 26, 27, and 28 present the residual plots for Clearing and Grubbing using transformed data. Data transformation solved the variance problem and improved the models precision.

Copies of the residual plots for all five activities are included in Appendix C. All activities experienced model improvement with logarithmic transformation.

Preliminary testing of the models suggested by the Cp procedure indicated problems when certain levels of a classification variable were dropped from the model and other levels were retained. Therefore, final models used were adjusted to contain all levels of classification variables, providing sufficient observations existed. This resulted in a small decrease in R^2, however, the utility of the models was greatly improved.

The final step in the regression procedure was to calculate the parameter estimates for the final model variables. Additionally, confidence intervals and prediction intervals for the observations were calculated.

Figures 29, 30, 31, 32, and 33 present the statistical results for the final prediction models. The highest R^2 obtained was 0.69 for Clearing and Grubbing and

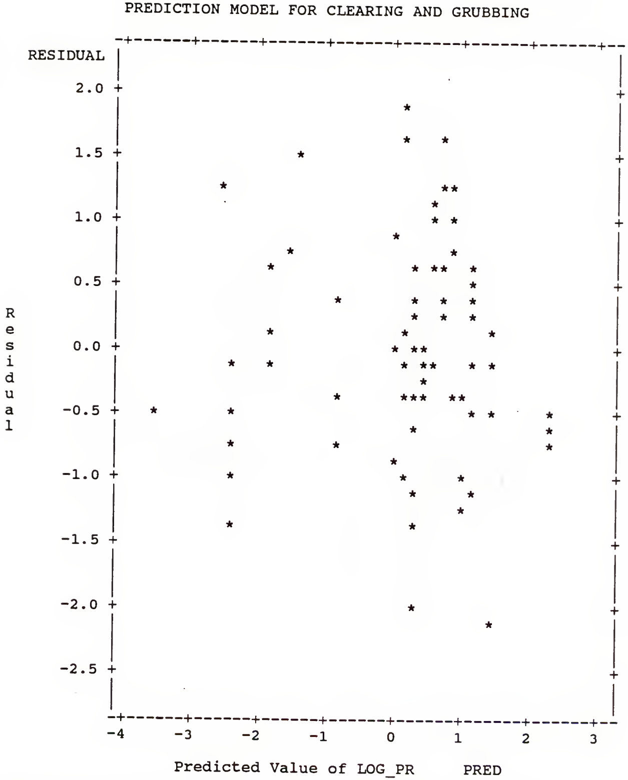

Figure 26.-Residual Plot of Production Rate Variable for Clear and Grubbing Using Transformed Data

PREDICTION MODEL FOR CLEARING AND GRUBBING

Plot of YRESID*LOG_TQ. Symbol used is '*'.

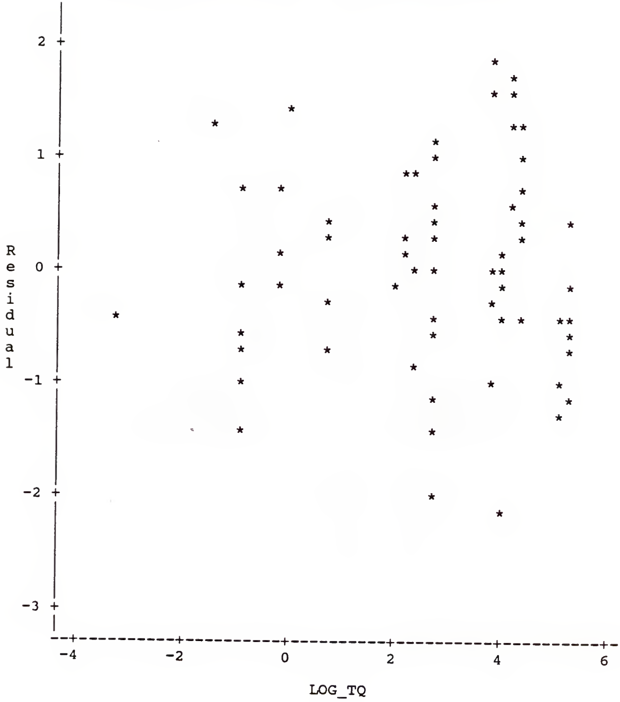

Figure 27.-Residual Plot of Total Quantity Variable for
Clear and Grubbing Using Transformed Data

PREDICTION MODEL FOR CLEARING AND GRUBBING

Plot of YRESID*LOG_PRI. Symbol used is '*'.

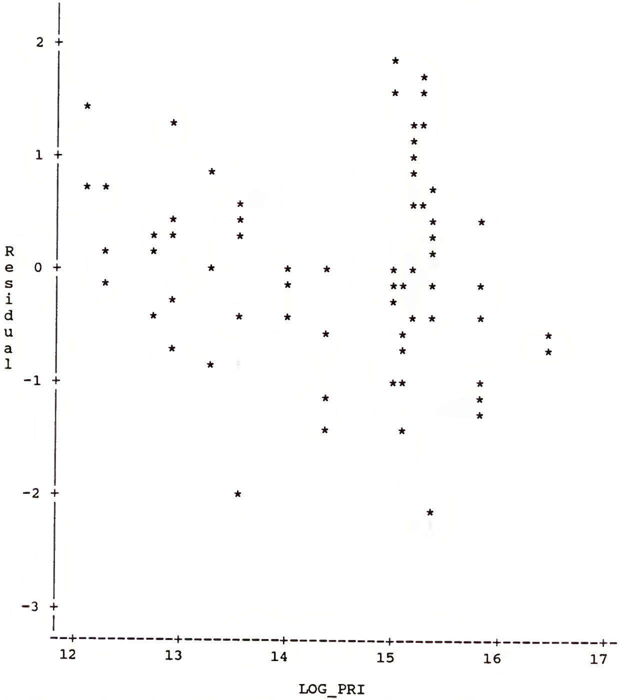

Figure 28.-Residual Plot of Price Variable for Clear and Grubbing Using Transformed Data

Source	Sum of Squares
Model	133.838
Error	59.778
Total	193.617

$F = 14.18$

$R^2 = 0.691$

Variable	Parameter Estimate	T
Production Rate = Intercept	-1.181892	-2.443
LOG Total Quantity	0.567505	4.895
Reconstruction	0.692154	1.584
Bridge	0.705082	1.137
Intersection	0.122397	0.212
New Construction	0.330528	0.532
Light Traffic	0.283303	0.427
Medium Traffic	0.054329	0.140
Medium Clearing	-0.244324	-0.514
Heavy Clearing	-0.021495	-0.039
Rural	-1.139281	-2.879
Urban	-0.578627	-1.417
Limited	-0.259863	-0.367

Figure 29.-Final Model for Clearing and Grubbing

Source	Sum of Squares	
Model	167.931	$F = 14.3$
Error	75.159	$R^2 = 0.691$
Total	243.090	

Variable	Parameter Estimate	T
Production Rate = Intercept	5.755543	4.988
Log Total Quantity	0.437740	6.493
Reconstruction	-2.554510	-2.624
Intersection	-3.820465	-3.675
New Construction	-1.786693	-1.795
Signalization	-2.846023	-2.350
Rural	-0.600389	-1.547
Urban	0.442833	1.126
Light Traffic	1.242225	1.872
Heavy Traffic	-0.943232	-0.752
Medium Traffic	0.209213	0.396
Lateral Ditch	0.122206	0.152
Regular Excavation	-0.339945	-0.641
Sand Soil	-0.733178	-2.026
Rock Soil	-0.569347	-0.771
Muck Soil	-0.058412	-0.087

Figure 30.-Final Model for Excavation

Source	Sum of Squares	
Model	111.706	$F = 6.094$
Error	167.785	$R^2 = 0.400$
Total	279.491	

Variable	Parameter Estimate	T
Production Rate = Intercept	3.557789	2.381
Log Total Quantity	0.333261	3.808
Reconstruction	1.592424	1.328
Bridge	2.434882	1.500
Intersection	0.394522	0.298
New Construction	1.687546	1.280
Signalization	0.931067	0.757
Rural	-1.062293	-1.693
Urban	-1.356593	-1.929
Light Traffic	0.710581	1.375
Heavy Traffic	-0.402573	-0.956
Sand - Clay	0.435642	0.540
Limerick	-0.697203	-1.142
Asphalt	0.175503	0.264

Figure 31.-Final Model for Base

Source	Sum of Squares	
Model	179.389	$F = 27.549$
Error	86.279	$R^2 = 0.675$
Total	265.669	

Variable	Parameter Estimate	T
Production Rate = Intercept	1.197071	1.184
Log Total Quantity	0.558623	10.189
Reconstruction	0.611475	1.007
Bridge	1.194745	1.824
Intersection	0.153371	0.233
New Construction	0.070499	0.104
Rural	0.423256	-1.130
Urban	0.199363	-0.484
Light Traffic	0.506167	0.593
Heavy Traffic	-0.465685	-0.549
Medium Traffic	-0.274218	-0.062
Limited	-0.274218	-0.567
Small Areas	-0.221864	01.286

Figure 32.-Final Model for Asphalt Pavement

Source	Sum of Squares	
Model	53.303	F = 8.105
Error	37.816	R^2 = 0.5850
Total	91.119	

Variable	Parameter Estimate	T
Production Rate = Intercept	2.830616	2.997
Log Total Quantity	0.286849	3.728
Reconstruction	-0.128761	-0.252
Intersection	-0.219912	-0.290
New Construction	-0.191264	-0.278
Signalization	-1.298789	-2.153
Rural	-0.146479	-0.313
Urban	-0.115760	-0.289
Heavy Traffic	-0.002649	-0.003
Medium Traffic	0.223525	0.273
Light Traffic	-0.461404	-0.473
Diameter	-0.029787	-2.750
Depth	0.026092	0.280

Figure 33.-Final Model for Storm Drains

the lowest was 0.40 for Base Installation. Recall that R^2 is the portion of the data variability accounted for by the model. Therefore, the final models account for approximately 40 to 70 percent the total variability. The large F values for the models indicate that the models are statistically highly significant.

A complete print out of the confidence and prediction intervals is included in Appendix C.

It should be noted that the final models include some variables with rather high probabilities of not effecting the dependent variable. These variables were not removed from the model because prediction accuracy was the primary objective of the model. If efficiency is also a consideration, then variables with a high probability of a greater T test statistic might be removed.

Furthermore, the model produced is a predictive model. That is, the parameter estimates were developed on the basis of improving the model's overall prediction precision. Taken individually they do not necessarily represent the exact contribution of the variable.

A summary of the regression procedure is given in Figure 34.

Step 1	Perform regression for all possible models. Select preliminary model on basis of Cp.
Step 2	Analyze residuals for selected model. Heterogenous variance indicated.
Step 3	Perform log transformation of the data.
Step 4	Perform regression for all possible models. select preliminary model on basis of cp.
Step 5	Analyze residuals for selected model. Variance acceptable.
Step 6	Produce parameter estimates, confidence intervals, and prediction intervals for final model.

Figure 34.-Summary of Regression Procedures Used in Model Development

Model Verification

Trial Procedure

Test data observations were obtained from two different projects for each of the five activities modelled. The test data sets contained the same type of factors measured in the original productivity survey. The test data were collected and recorded in the same manner as the model data base. None of the test observations were used in model development.

Using the factorial data from the test observations, a predicted mean production rate was calculated using the model previously developed. Actual production rate observations were compared to the predicted values.

Tables 9 through 20 present the prediction calculations for the different activities. The factorial data for the storm drain activity varied from observation to observation, therefore, several predictions were made for storm drain production rate. However, the factorial data were constant for the other activities for all observations. This resulted in a single prediction for average production rate.

The results of the actual versus prediction comparisons are presented in Table 21.

Generally, the precision of the models appeared related to R^2 the coefficient of determination. Activity models with the highest R^2 resulted in the highest estimate precision. This seems to be in agreement with

Table 9. - Calculation of Prediction Value for Clearing and Grubbing Test 1

MODEL PREDICTION OF MEAN PRODUCTION RATE

TEST 1 — Activity: Clearing And Grubbing

FDOT Project: 1520-3610

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	-1.182	1	-1.182	-1.182
Log Total Quantity	0.568	57.91	4.058890081	2.305
Reconstruction	0.692	1		0.692
New Bridge	0.705	0		0.000
Intersection	0.122	0		0.000
New Construction	0.331	0		0.000
Signalization	0.000	0		0.000
Light	0.283	1		0.283
Medium	0.054	0		0 000
Heavy	0	0		0.000
Medium Clearing	-0.244	0		0.000
Heavy Clearing	-0.201	1		-0.201
Rural	-1.140	1		-1.140
Urban	-0.579	0		0.000
Limited	-0.260	0		0.000
				0.000
				0.000
				0.000
Predicted Mean Production Rate (Log)				0.757
Predicted Mean Production Rate				2.133 Acres/Day

Table 10. - Calculation of Prediction Value for Clearing and Grubbing Test 2

	MODEL PREDICTION OF MEAN PRODUCTION RATE
TEST 2	Activity: Clearing And Grubbing
	FDOT Project: 60060-3507

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	-1.182	1	-1.182	-1.182
Log Total Quantity	0.568	1.54	0.431782416	0.245
Reconstruction	0.692	0		0.000
New Bridge	0.705	1		0.705
Intersection	0.122	0		0.000
New Construction	0.331	0		0.000
Signalization	0.000	0		0.000
Light	0.283	1		0.283
Medium	0.054	0		0 000
Heavy	0	1		0.000
Medium Clearing	-0.244	0		0.000
Heavy Clearing	-0.201	1		-0.201
Rural	-1.140	1		-1.140
Urban	-0.579	0		0.000
Limited	-0.260	0		0.000
				0.000
				0.000
				0.000
Predicted Mean Production Rate (Log)				-1.290
Predicted Mean Production Rate				0.275 Acres/Day

Table 11. - Calculation of Prediction Value for Excavation Test 1

	MODEL PREDICTION OF MEAN PRODUCTION RATE
TEST 1	Activity: Excavation
	FDOT Project: 2010-3523

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	5.755	1	5.755	5.755
Log Total Quantity	0.438	145475	11.88775952	5.203
Reconstruction	-2.550	1		-2.550
New Bridge	0.000	0		0.000
Intersection	-3.820	0		0.000
New Construction	-1.790	1		-1.790
Signalization	-2.846	0		0.000
Light	1.242	1		1.242
Medium	0.209	1		0.209
Heavy	-0.943	0		0.000
Rural	-0.600	0		0.000
Urban	0.442	1		0.442
Limited	0.000	0		0.000
Lateral Ditch Excav	-0.579	0		0.000
Regular Excav	-0.260	1		-0.260
Sand Soil	-0.733	1		-0.733
Rock Soil	-0.569	0		0.000
Muck Soil	-0.058	0		0.000
Predicted Mean Production Rate (Log)				7.518
Predicted Mean Production Rate				1840.831 CY/Day

Table 12. - Calculation of Prediction Value for Excavation Test 2

MODEL PREDICTION OF MEAN PRODUCTION RATE

TEST 2 Activity: Excavation

FDOT Project:
70220-3429

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	5.755	1	5.755	5.755
Log Total Quantity	0.438	116329	11.66417766	5.105
Reconstruction	-2.550	1		2.550
				0.000
Intersection	-3.820	0		0.000
New Construction	-1.790	0		0.000
Signalization	-2.846	0		0.000
Light	1.242	0		0.000
Medium	0.209	1		0.209
Heavy	-0.943	0		0.000
Rural	-0.600	0		0.000
Urban	0.442	0		0.000
				0.000
Lateral Ditch Excav	-0.579	0		0.000
Regular Excav	-0.260	1		-0.260
Sand Soil	-0.733	1		-0 733
Rock Soil	-0.569	0		0.000
Muck Soil	-0 058	0		0 000
Predicted Mean Production Rate (Log)				7.526
Predicted Mean Production Rate				1855.873 CY/Day

Table 13. - Calculation of Prediction Value for Base Test 1

MODEL PREDICTION OF MEAN PRODUCTION RATE

Activity: Base

FDOT Project:
11140-3507

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	3.558	1	3.558	3.558
Log Total Quantity	0.333	7701	8.949105469	2.980
Reconstruction	1.592	1		1.592
Bridge	2.434			0.000
Intersection	0.395	0		0.000
New Construction	1.687	0		0.000
Signalization	0.931	0		0.000
Light	0.711	0		0.000
				0.150
Heavy	-0.402			
	5	0		0.000
Rural	-1.062	1		-1.062
Urban	-1.357	0		0 000
Sand-clay				0.000
Limerock	-0.579	1		-0.579
Asphalt	-0.260	0		0.000
				0.000
				0.000
				0.000
Predicted Mean Production Rate (Log)				6.639
Predicted Mean Production Rate				764.370 SY/Day

Table 14. - Calculation of Prediction Value for Base Test 2

MODEL PREDICTION OF MEAN PRODUCTION RATE

Activity: Base

FDOT Project:
36090-3506

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	3.558	1	3.558	3.558
Log Total Quantity	0.333	76799	11.24894689	3.746
Reconstruction	1.592	1		1.592
Bridge	2.434			0.000
Interjection	0.395	0		0.000
New Construction	1.687	0		0.000
Signalization	0.931	0		0.000
Light	0.711	1		0.711
Heavy	-0.402 5	0		0.000
Rural	-1.062	1		-1.062
Urban	-1.357	0		0.000
Sand-clay				0.000
Limerock	-0.579	1		-0.579
Asphalt	-0.260	0		0.000
				0.000
				0.000
				0.000
Predicted Mean Production Rate (Log)				7.966
Predicted Mean Production Rate				2881.019 SY/Day

Table 15. - Calculation of Prediction Value for Asphalt Pavement Test 1

	MODEL PREDICTION OF MEAN PRODUCTION RATE
TEST 1	Activity: Asphalt
	FDOT Project: 36090-3506

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	1.197	1	1.197	1.197
Log Total Quantity	0.559	35738	10.48396982	5.856
Reconstruction	0.611	1		0.611
Bridge	1.195	0		0.000
Intersection	0.153	0		0.000
New Construction	0.070	0		0.000
Light	0.506	1		0.506
Medium	-0.051	0		0.000
Heavy	-0.466	0		0.000
Rural	-0.423	1		-0.423
Urban	-0.199	0		0.000
Limited	-0.274	0		0.000
Small Areas	-0.579	0		0.000

Predicted Mean Production Rate (Log)	7.748
Predicted Mean Production Rate	2316.268 Tons/Day

Table 16. - Calculation of Prediction Value for Asphalt Pavement Test 2

	MODEL PREDICTION OF MEAN PRODUCTION RATE
TEST 2	Activity: Asphalt
	FDOT Project: 36090-3506

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	1.197	1	1.197	1.197
Log Total Quantity	0.559	1311	7.178545483	4.010
Reconstruction	0.611	0		0.000
Bridge	1.195	1		1.195
Intersection	0.153	0		0.000
New Construction	0.070	0		0.000
Light	0.506	0		0.000
Medium	-0.051	1		-0.051
Heavy	-0.466	0		0.000
Rural	-0.423	0		0.000
Urban	-0.199	1		-0.199
Limited	-0.274	0		0.000
Small Areas	-0.579	0		0.000
Predicted Mean Production Rate (Log)				6.151
Predicted Mean Production Rate				469.391 Tons/Day

Table 17. -Calculation of Prediction Value for Storm Drains Test 1, Observations 1 and 2

MODEL PREDICTION OF MEAN PRODUCTION RATE

TEST 1
Obs. 1, 2

Activity: Storm Drain

FDOT Project:
02010-3523

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	2.831	1	2.8306	2.831
Log Total Quantity	0.287	1026	6.933423025	1.989
Reconstruction	-0.129	1		-0.129
				0.000
Intersection	-0.220	0		0.000
New Constriction	-0.191	0		0.000
Signalization	-1.299	0		0.000
Light	-0.461	0		0.000
Medium	0.224	1		0.224
Heavy	-0.003	0		0.000
Rural	-0.146	0		0.000
Urban	-0.116	1		-0.116
Diameter	-0.030	30		-0.891
Depth	0.026	5		0.131
Predicted Mean Production Rate (Log)				4.038
Predicted Mean Production Rate				56.696 LF/Day

Table 18. - Calculation of Prediction Value for Storm Drains Test 1, Observation 3

MODEL PREDICTION OF MEAN PRODUCTION RATE

Activity: Storm Drain

FDOT Project:
02010-3523

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	2.831	1	2.8306	2.831
Log Total Quantity	0.287	1026	6.933423025	1.989
Reconstruction	-0.129	1		-0.129
				0.000
Interjection	-0.220	0		0.000
New Construction	-0.191	0		0.000
Signalization	-1.299	0		0.000
Light	-0.461	0		0.000
Medium	0.224	1		0.224
Heavy	-0 003	0		0.000
Rural	-0.146	0		0.000
Urban	-0.116	1		-0.116
Diameter	-0.030	30		-0.891
Depth	0.026	6		0.157
Predicted Mean Production Rate (Log)				4.064
Predicted Mean Production Rate				58.195 LF/Day

Table 19. -Calculation of Prediction Value for Storm Drains Test 1, Observations 4 and 5

MODEL PREDICTION OF MEAN PRODUCTION RATE

TEST 1
Obs. 4, 5

Activity: Storm Drain

FDOT Project:
02010-3523

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	2.831	1	2.8306	2.831
Log Total Quantity	0.287	1026	6.933423025	1.989
Reconstruction	-0.129	1		-0.129
				0.000
Intersection	-0.220	0		0.000
New Construction	-0.191	0		0.000
Signalization	-1.299	0		0.000
Light	-0.461	0		0.000
Medium	0.224	1		0.224
Heavy	-0.003	0		0.000
Rural	-0.146	0		0.000
Urban	-0.116	1		-0.116
Diameter	-0.030	15		-0.446
Depth	0.026	3		0.078
Predicted Mean Production Rate (Log)				4.431
Predicted Mean Production Rate				84.016 LF/Day

Table 20. - Calculation of Prediction Value for Storm Drains Test 2

MODEL PREDICTION OF MEAN PRODUCTION RATE

TEST 2 Activity: Storm Drain

FDOT Project:
48731-3604

Factor	Parameter Estimate	Observed Variable Value	Transformed Variable Value	PR Factor
Intercept	2.831	1	2.8306	2 831
Log Total Quantity	0.287	920	6.82437367	1.957
Reconstruction	-0.129	0		0.000
				0.000
Intersection	-0.220	1		-0.220
New Construction	-0.191	0		0.000
Signalization	-1.299	0		0 000
Light	-0.461	0		0 000
Medium	0.224	1		0 224
Heavy	-0.003	0		0 000
Rural	-0.146	0		0.000
Urban	-0 116	1		-0 116
Diameter	-0 030	18		-0 535
Depth	0.026	2.5		0.065
Predicted Mean Production Rate (Log)				4.206
Predicted Mean Production Rate				67.113 LF/Day

Table 21. - Summary of Model Verification Testing

Activity Units Test No. Project No.	Obs. No.	Actual Production Rate	Predicted Production Rate	Actual Production Rate MEAN	Predicted Production Rate MEAN
Clear and Grub Acres/Day	1	3.44	2.13	3.34	2.13
	2	2.13	2.13		
	3	2.82	2.13		
	4	4.96	2.13		
Test 1 01520-3610	5	3.37	2.13		
	1	0.17	0.28	0.31	0.28
	2	0.23	0.28		
Test 2 60060-3507	3	0.66	0.28		
	4	0.15	0.28		
	5	0.33	0.28		
Excavation cy/Day	1	1800	1840	1282	1840
	2	1548	1840		
	3	1428	1840		
Test 1 02010-3523	4	732	1840		
	5	900	1840		
	1	1296	1856	1781	1856
Test 2 70220-3429	2	2136	1856		
	3	1968	1856		
	4	1608	1856		
	5	1896	1856		
Base sy/Day	1	767	764	1387	764
	2	1600	764		
	3	2767	764		
Test 1 11140-3507	4	1533	764		
	5	267	764		
	1	2172	2881	4117	2881
Test 2 36090-3506	2	3164	2881		
	3	6422	2881		
	4	5194	2881		
	5	3635	2881		
Asphalt Pavement Tons/Day	1	2022	2316	1993	2316
	2	2213	2316		
	3	1052	2316		
	4	2320	2316		
Test 1 36090-3506	5	2359	2316		
	1	261	469	207	469
	2	106	469		
Test 2 02010-3523	3	122	469		
	4	274	469		
	5	274	469		
Storm Drains LF/Day	1	160	57	110	68
	2	56	57		
	3	160	58		
	4	104	84		
Test 1 02010-3523	5	72	84		
	1	85	67	173	67
	2	104	67		
Test 2 48731-3604	3	180	67		
	4	400	67		
	5	94	67		

the statistical fundamentals which were used to derive the models.

The models all appeared to provide reasonable prediction of actual production rates. In some cases the precision of the prediction was surprisingly good. However, it must be remembered that these are probabilistic models and as such can never make exact predictions. The reader is encouraged to review the listing of predicted and actual values of each observation used in the input data sets. This information is provided with the SAS regression output as Appendix C. Reviewing the complete list of observations provides a better feel for the possible range of variance between actual and predicted values.

Summary

This chapter presented an example of a trial application of the production rate modeling system to actual highway construction projects. A total of 60 projects were surveyed throughout the state of Florida. The data base used for model development contained 645 observations with measurements of 30 distinct influencing factors. From this data base production rate models were developed for five typical construction activities.

The model selection and regression solutions were performed with the assistance of computer software.

Following model development, each of the five models was checked with test data obtained from highway

construction projects. Test predictions indicated the models were producing reasonable output.

The next and final chapter will summarize the production rate modeling system and review important points recognized during this study. Also, a number of areas which present opportunities for future research will be discussed.

CHAPTER 9

SUMMARY AND CONCLUSIONS

Research Summary

Problem Statement

Production rate information is essential to many construction management functions. Estimating, planning, scheduling and resource management all depend upon production rate data. Inaccurate production rate information results in costly erroneous decisions by management.

In spite of the importance of accurate, timely production rate values, predicting construction productivity can be difficult. There are many factors which influence construction work rates. These many factors are subject to change and are as dynamic as the construction process itself. Each new project presents a seemingly new set of influencing factors. Traditional prediction methods, such as using historical averages, often provide misleading information.

Research Objective

The fundamental hypothesis of this study is that the variance in construction production rates results from a

large number of influencing factors. By identifying and measuring these influencing factors much of the variance can be explained. Using a data base of specifically structured field observations, a model for predicting future production rates can be developed.

The purpose of this research was to develop a factorial modeling system for improving the accuracy of production rate predictions, or more specifically to address each phase of the modeling system and to present those techniques which are most appropriate for use with construction production rate data. Finally, the modeling procedure was to be demonstrated with actual highway construction production rate data.

Summary

The production rate modeling system encompasses many considerations. Development must begin with an analysis of the construction process. Understanding the underlying process to be model is an essential prerequisite. Work activities must be identified and standards for production rate measuring must be established. The next step involves developing a list of preliminary construction production rate factors. The input of experienced field personnel is mandatory in identifying influencing factors. Design and implementation of a data collection system follows the preliminary studies. Development of the prediction model involves application of statistical regression procedures to the data base of observational

data. Verification and model testing conclude the modelling system.

Figure 35 presents a schematic flow chart of the modeling system. Because of the dynamic nature of the construction process, the production rate modeling system should be a continuous process. As new observational data is obtained, the model is updated to include the latest information.

Concusions

Validity of the Factorial Model

Discussion of the subject of modeling construction production rates was begun with the concept of the factorial model. That is that the production rate observed for a given activity is the combined result of a number of influencing factors. Identification and quantification of the influencing factors will allow for more precise predictions of production rates. The factorial model concept is a valid and useful approach to understanding and predicting construction production rates.

Need for a Comprehensive System

An organizational model for predicting construction production rates consists of a system with several components. These component modules include data collection, data management, factor selection, statistical

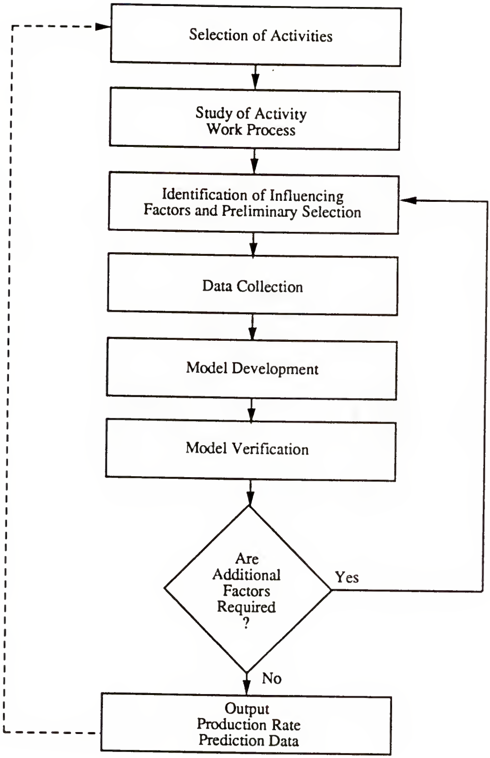

Figure 35. – Schematic Flow Chart of the Production Rate Modeling System

model development and reporting of output. Attention must be given to each of these areas.

Characteristics of Production Rate Data

Construction production rate data possesses several unique characteristics. First, the data are highly variable. Research also indicates that the data are typically non-normal with a pronounced skew to the higher values. Finally, analysis of the data collected in this study shows heterogeneous variances for the random error terms.

Statistical Modeling Procedures

Successful modeling of construction productions rates requires the careful selection and screening of influencing factors. Appropriate sample size can be estimated as approximately four times the number of independent variable combinations. This will allow sufficient data for both modeling and estimating the error component.

Heterogeneous variance problems were solved in the demonstration model by using logrythmic transformations. Even though the data were clearly not normally distributed, the least squares regression procedures did produce useful results.

Results of Model Demonstration

The application of the modeling system to an actual construction environment provided several interesting results. The model was successful in explaining a

significant portion of the overall variation. Much of the unexplained variation undoubtedly results from influencing factors which were not included in the model. Organizational factors, for example, were not included. The owner did not know in advance which contracting organization would be performing the work. If the modeling system was applied within the context of a construction contracting organization, organizational factors could be included in the model. This certainly would greatly improve the prediction precision.

Of the influencing factors selected for inclusion in the demonstration, model, the total quantity of work for the activity appeared to be the largest affect. Projects with larger volumes of work experienced higher work rates. Perhaps a larger volume of work encourages the contractor to commit more resources to the work effort.

Applicability to Other Forms of Construction

This study concentrated on highway construction. However, there is no reason to believe that the factorial modeling concepts would not be completely appropriate for other construction categories such as building construction. The principles are the same. The only difference is that the influencing factors will be unique to the particular work setting.

Recommendations for Future Research

Development of a Reliable Listing of Influencing Factors

A great deal of basic research needs to be done in identifying and categorizing influencing factors for various construction activities and construction settings. If reliable listing of influencing factors were available, model development and initial data collection would be expedited. At this point, the modeling system must begin with exploratory procedures.

Expert Systems to Assist in Factor Section and Model Development

The process of factorial review and selection, and model development are prime candidates for expert systems. The proper application of current artificial intelligence technology to the production rate modeling system would significantly improve the cost-benefit ratio.

Advanced Statistical Methods

Even though acceptable results were obtained with the general linear model, many non-parametric statistical procedures have been developed. Different statistical procedures need to be tried and the results compared. Application of non-parametric and messy data techniques may provide additional model precision.

APPENDIX A

EXAMPLE OF DATA COLLECTION FORMS

COLLEGE
OF
ENGINEERING

UNIVERSITY OF FLORIDA

GAINESVILLE, FLORIDA 32611
AREA CODE 904 PHONE 392-0933

DEPARTMENT OF CIVIL ENGINEERING

SPECIAL RESEARCH PROJECT
for
FLORIDA DEPARTMENT OF TRANSPORTATION

GENERAL INSTRUCTIONS

1. Select at least three projects. Try to pick different types of jobs such as new construction vs. reconstruction. Also, try to select jobs with different locations such as urban vs rural.

2. The information required consist of one page of general information about the project and one survey page for each different work activity. (Additional forms have been enclosed for the EXCAVATION category because it may be that a single project will involve more than one type of excavation.)

3. Field engineers should record contractor production quantities for all of the work items which are included in the project.

4. Return the forms as soon as they are completed to:

UNIVERSITY OF FLORIDA
DEPARTMENT OF CIVIL ENGINEERING
346 WEIL HALL
GAINESVILLE, FLORIDA 32611
ATTN: RALPH D. ELLIS, JR.

IF YOU HAVE ANY QUESTIONS OR NEED ANY ADDITIONAL INFORMATION PLEASE, TELEPHONE:

RALPH D. ELLIS, JR.
(904) 392-1085
OR
622-1085 SUNCOM

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FLORIDA DEPARTMENT OF TRANSPORTATION

PROJECT GENERAL INFORMATION
(Please, see instructions on reverse side.)

1. PROJECT TITLE: ______________________________
2. STATE PROJECT JOB NO.: ______________________
3. TOTAL CONTRACT PRICE OF THE JOB: $ ______________
4. THIS PROJECT WOULD BE CATEGORIZED AS:

   ___ RECONSTRUCTION OF AN EXISTING ROAD
   ___ CONSTRUCTION OF A NEW ROAD
   ___ IMPROVEMENTS TO AN INTERSECTION
   ___ SIGNALIZATION
   ___ BRIDGE

   OTHER ______________________________

5. THIS PROJECT IS LOCATED IN ______________ COUNTY.
6. LOCAL CONDITIONS:

   ___ RURAL
   ___ URBAN
   ___ LIMITED ACCESS ROAD (INTERSTATE)

7. TRAFFIC CONDITIONS:

   ___ LIGHT
   ___ MEDIUM
   ___ HEAVY

8. FDOT RESIDENT ENGINEER ______________________ DATE: ________

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DEPARTMENT OF CIVIL ENGINEERING

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FLORIDA DEPARTMENT OF TRANSPORTATION

FIELD OBSERVATIONS
(Please, see instructions on reverse side.)

WORK ACTIVITY: **CLEARING and GRUBBING**

1. STATE PROJECT JOB NO.: ____________________

2. TOTAL QUANTITY OF WORK IN THE JOB: __________ acres

3. OBSERVED PRODUCTION QUANTITIES:

DATE: __________ QUANTITY: __________ acres NO. HOURS WORKED: __________
DATE: __________ QUANTITY: __________ acres NO. HOURS WORKED: __________
DATE: __________ QUANTITY: __________ acres NO. HOURS WORKED: __________
DATE: __________ QUANTITY: __________ acres NO. HOURS WORKED: __________
DATE: __________ QUANTITY: __________ acres NO. HOURS WORKED: __________

4. TYPE OF CLEARING AND GRUBBING WORK:

___ light : grass and scattered brush
___ medium : brush and scattered trees
___ heavy : heavy brush and large trees

5. FACTORS WHICH HAD AN EFFECT ON PRODUCTION:

___ WEATHER (RAIN)
___ TRAFFIC
___ INSUFFICIENT MANPOWER OR EQUIPMENT
___ UTILITY DELAYS
___ PHASING OF WORK REQUIRED BY CONTRACT
___ BURNING NOT ALLOWED
___ OTHER ____________________
___ OTHER ____________________

6. FDOT Project Engineer ____________________ DATE: __________

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FIELD OBSERVATIONS
(Please, see instructions on reverse side.)

WORK ACTIVITY: EXCAVATION

1. STATE PROJECT JOB NO.: ____________________
2. TOTAL QUANTITY OF WORK IN THE JOB: ____________ Cu. Yds.
3. OBSERVED PRODUCTION QUANTITIES:
   DATE: ________ QUANTITY: ________ Cu.Yds. NO. HOURS WORKED: ______
   DATE: ________ QUANTITY: ________ Cu.Yds. NO. HOURS WORKED: ______
   DATE: ________ QUANTITY: ________ Cu.Yds. NO. HOURS WORKED: ______
   DATE: ________ QUANTITY: ________ Cu.Yds. NO. HOURS WORKED: ______
   DATE: ________ QUANTITY: ________ Cu.Yds. NO. HOURS WORKED: ______
4. TYPE OF EXCAVATION WORK:
   ___ REGULAR
   ___ LATTERAL DITCH
   ___ SUBSOIL
5. TYPE OF MATERIAL
   ___ SAND
   ___ CLAY
   ___ ROCK
6. FACTORS WHICH HAD AN EFFECT ON PRODUCTION:
   ___ WEATHER (RAIN)
   ___ TRAFFIC
   ___ INSUFFICIENT MANPOWER OR EQUIPMENT
   ___ UTILITY DELAYS
   ___ PHASING OF WORK REQUIRED BY CONTRACT
   ___ OTHER ____________________
   ___ OTHER ____________________
7. FDOT PROJECT ENGINEER ____________________ DATE: __________

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FIELD OBSERVATIONS
(Please, see instructions on reverse side.)

WORK ACTIVITY: **BASE CONSTRUCTION**

1. STATE PROJECT JOB NO.: ______________________
2. TOTAL QUANTITY OF WORK IN THE JOB: ______________ Sq. Yds.
3. OBSERVED PROOUCTION QUANTITIES:

   OATE: ________ QUANTITY: ________ Sq.Yds. NO. HOURS WORKEO: ______
   OATE: ________ QUANTITY: ________ Sq.Yds. NO. HOURS WORKEO: ______
   OATE: ________ QUANTITY: ________ Sq.Yds. NO. HOURS WORKEO: ______
   OATE: ________ QUANTITY: ________ Sq.Yds. NO. HOURS WORKEO: ______
   OATE: ________ QUANTITY: ________ Sq.Yds. NO. HOURS WORKEO: ______

4. TYPE OF MATERIAL
   ___ SANO CLAY
   ___ LIMEROCK
   ___ SHELL STABILIZEO
   ___ SOIL CEMENT
   ___ ASPHALTIC BASE

5. FACTORS WHICH HAO AN EFFECT ON PROOUCTION:
   ___ WEATHER (RAIN)
   ___ TRAFFIC
   ___ INSUFFICIENT MANPOWER OR EQUIPMENT
   ___ UTILITY OELAYS
   ___ PHASING OF WORK REQUIREO BY CONTRACT
   ___ OTHER ______________________
   ___ OTHER ______________________

6. FOOT PROJECT ENGINEER ______________________ OATE: __________

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FIELD OBSERVATIONS
(Please, see instructions on reverse side.)

WORK ACTIVITY: **PLANT MIX SURFACE** (STRUCTURAL COURSE)

1. STATE PROJECT JOB NO.: ______________________
2. TOTAL QUANTITY OF WORK IN THE JOB: ______________ Tons
3. OBSERVED PRODUCTION QUANTITIES

   DATE: ________ QUANTITY: ________ Tons NO. HOURS WORKED: ______
   DATE: ________ QUANTITY: ________ Tons NO. HOURS WORKED: ______
   DATE: ________ QUANTITY: ________ Tons NO. HOURS WORKED: ______
   DATE: ________ QUANTITY: ________ Tons NO. HOURS WORKED: ______
   DATE: ________ QUANTITY: ________ Tons NO. HOURS WORKED: ______

4. FACTORS WHICH HAD AN EFFECT ON PRODUCTION:

   ___ WEATHER (RAIN)
   ___ TRAFFIC
   ___ INSUFFICIENT MANPOWER OR EQUIPMENT
   ___ UTILITY DELAYS
   ___ PHASING OF WORK REQUIRED BY CONTRACT
   ___ OTHER ______________________________
   ___ OTHER ______________________________

5. FDOT PROJECT ENGINEER ______________________ DATE: __________

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AREA CODE 904 PHONE 392-0933

DEPARTMENT OF CIVIL ENGINEERING

SPECIAL RESEARCH PROJECT
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FLORIDA DEPARTMENT OF TRANSPORTATION

FIELD OBSERVATIONS
(Please, see instructions on reverse side.)

WORK ACTIVITY: STORM SEWERS

1. STATE PROJECT JOB NO.: ____________________

2. TOTAL QUANTITY OF WORK IN THE JOB: ____________ L.F.

3. OBSERVED PRODUCTION QUANTITIES:

DATE:_______ QUANTITY:______L.F. AVE.DEPTH:_____Ft. AVE.DIA.:_____In. HRS. WORKED:_____
DATE:_______ QUANTITY:______L.F. AVE.DEPTH:_____Ft. AVE.DIA.:_____In. HRS. WORKED:_____
DATE:_______ QUANTITY:______L.F. AVE.DEPTH:_____Ft. AVE.DIA.:_____In. HRS. WORKED:_____
DATE:_______ QUANTITY:______L.F. AVE.DEPTH:_____Ft. AVE.DIA.:_____In. HRS. WORKED:_____
DATE:_______ QUANTITY:______L.F. AVE.DEPTH:_____Ft. AVE.DIA.:_____In. HRS. WORKED:_____

4. FACTORS WHICH HAD AN EFFECT ON PRODUCTION:

___ WEATHER (RAIN)
___ TRAFFIC
___ INSUFFICIENT MANPOWER OR EQUIPMENT
___ UTILITY DELAYS
___ PHASING OF WORK REQUIRED BY CONTRACT
___ OTHER ____________________
___ OTHER ____________________

5. FDOT PROJECT ENGINEER ____________________ DATE: __________

APPENDIX B

DATA BASE OF ACTIVITY OBSERVATIONS

Glossary of Variable Names Used in Data Base

Project Number	=	FDOT Project Number
Production Rate	=	Daily Observed Production Rate
F1	=	Total Activity Work Quantity
F2	=	Total Project Price
F3	=	Project Type: Reconstruction
F4	=	Project Type: Bridge
F5	=	Project Type: Intersection
F6	=	Project Type: New Construction
F7	=	Project Type: Signalization
F8	=	Project Location: Rural
F9	=	Project Location: Urban
F10	=	Project Location: Limited Access
F11	=	Traffic: Light
F12	=	Traffic: Medium
F13	=	Traffic: Heavy
C1	=	Light Clearing
C2	=	Medium Clearing
C3	=	Heavy Clearing
E1	=	Regular Excavation
E2	=	Latteral Ditch Excavation
E3	=	Subsoil Excavation
E4	=	Sand Soil
E5	=	Rock Soil
E6	=	Muck Soil
B1	=	Sand-Clay Base
B2	=	Limerock Base
B3	=	Asphalt Base
A1	=	Small Area Pavement
ST1	=	Depth of Sewer
ST2	=	Diameter of Sewer

DATA SET FOR CLEARING AND GRUBBING

OBS	PROJECT NUMBER	PRODUCTION RATE ACRES/DAY	F1	F2
1	02010-3523	1.000	8.000	3132002.00
2	02010-3523	1.000	8.000	3132002.00
3	02010-3523	1.000	8.000	3132002.00
4	02010-3523	1.000	8.000	3132002.00
5	02010-3523	1.000	8.000	3132002.00
6	02010-3532	0.400	0.400	177625.00
7	03175-3407	4.500	180.000	14380126.00
8	03175-3407	5.650	180.000	14380126.00
9	03175-3407	5.650	180.000	14380126.00
10	03175-3407	5.100	180.000	14380126.00
11	10020-3513	0.840	42.000	3185151.00
12	10020-3513	7.980	42.000	3185151.00
13	10020-3513	5.880	42.000	3185151.00
14	10020-3513	1.260	42.000	3185151.00
15	10020-3513	0.420	42.000	3185151.00
16	10160-3525	3.800	69.490	4319100.35
17	10160-3525	7.250	69.490	4319100.35
18	10160-3525	11.190	69.490	4319100.35
19	10160-3525	10.330	69.490	4319100.35
20	10160-3525	10.330	69.490	4319100.35

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	C1	C2	C3
1	0	1	0	0	0	0	1	0	0	1	0	0	0	1
2	0	1	0	0	0	0	1	0	0	1	0	0	0	1
3	0	1	0	0	0	0	1	0	0	1	0	0	0	1
4	0	1	0	0	0	0	1	0	0	1	0	0	0	1
5	0	1	0	0	0	0	1	0	0	1	0	0	0	1
6	1	0	0	0	0	0	1	0	0	0	1	0	0	1
7	1	0	0	0	0	0	0	1	0	1	0	0	0	0
8	1	0	0	0	0	0	0	1	0	1	0	0	0	0
9	1	0	0	0	0	0	0	1	0	1	0	0	0	0
10	1	0	0	0	0	0	0	1	0	1	0	0	0	0
11	0	0	0	1	0	1	0	0	0	1	0	0	0	1
12	0	0	0	1	0	1	0	0	0	1	0	0	0	1
13	0	0	0	1	0	1	0	0	0	1	0	0	0	1
14	0	0	0	1	0	1	0	0	0	1	0	0	0	1
15	0	0	0	1	0	1	0	0	0	1	0	0	0	1
16	0	0	0	1	0	0	1	0	0	0	1	0	1	0
17	0	0	0	1	0	0	1	0	0	0	1	0	1	0
18	0	0	0	1	0	0	1	0	0	0	1	0	1	0
19	0	0	0	1	0	0	1	0	0	0	1	0	1	0
20	0	0	0	1	0	0	1	0	0	0	1	0	1	0

DATA SET FOR CLEARING AND GRUBBING

OBS	PROJECT NUMBER	PRODUCTION RATE ACRES/DAY	F1	F2
21	11140-3507	3.000	8.650	345775
22	11140-3507	3.000	8.650	345775
23	11140-3507	2.650	8.650	345775
24	12020-3534	0.100	.	1369359
25	12020-3534	0.120	.	1369359
26	16510-3605	1.100	56.970	1250680
27	16510-3605	1.400	56.970	1250680
28	16510-3605	1.300	56.970	1250680
29	16510-3605	1.700	56.970	1250680
30	16510-3605	1.600	56.970	1250680
31	35350-3502	0.490	.	2997476
32	35350-3502	0.130	.	2997476
33	35350-3502	0.230	.	2997476
34	35350-3502	0.270	.	2997476
35	35350-3502	0.650	.	2997476
36	46010-3529	4.845	9.689	3933859
37	46040-3545	1.040	1.040	182576
38	48060-3506	8.230	82.260	4026596
39	48060-3506	8.230	82.260	4026596
40	48060-3506	1.640	82.260	4026596

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	C1	C2	C3
21	1	0	0	0	0	0	0	0	0	1	0	0	0	1
22	1	0	0	0	0	0	0	0	0	1	0	0	0	1
23	1	0	0	0	0	0	0	0	0	1	0	0	0	1
24	1	0	0	0	0	0	1	0	0	0	1	0	1	0
25	1	0	0	0	0	0	1	0	0	0	1	0	1	0
26	1	0	0	0	0	1	0	0	0	1	0	0	1	0
27	1	0	0	0	0	1	0	0	0	1	0	0	1	0
28	1	0	0	0	0	1	0	0	0	1	0	0	1	0
29	1	0	0	0	0	1	0	0	0	1	0	0	1	0
30	1	0	0	0	0	1	0	0	0	1	0	0	1	0
31	0	0	0	1	0	1	0	0	0	0	1	0	0	1
32	0	0	0	1	0	1	0	0	0	0	1	0	0	1
33	0	0	0	1	0	1	0	0	0	0	1	0	0	1
34	0	0	0	1	0	1	0	0	0	0	1	0	0	1
35	0	0	0	1	0	1	0	0	0	0	1	0	0	1
36	0	1	0	0	0	0	0	0	0	0	1	0	0	1
37	0	0	0	0	0	0	0	0	0	0	1	0	0	1
38	1	0	0	0	0	1	0	0	0	0	1	0	1	0
39	1	0	0	0	0	1	0	0	0	0	1	0	0	0
40	1	0	0	0	0	1	0	0	0	0	1	0	0	0

DATA SET FOR CLEARING AND GRUBBING

OBS	PROJECT NUMBER	PRODUCTION RATE ACRES/DAY	F1	F2
41	48060-3506	6.580	82.260	4026596
42	48731-3604	0.130	0.850	209372
43	48731-3604	0.170	0.850	209372
44	48731-3604	0.130	0.850	209372
45	48731-3604	0.130	0.850	209372
46	48731-3604	0.290	0.850	209372
47	53030-3510	1.700	172.000	7205002
48	53030-3510	1.000	172.000	7205002
49	53030-3510	1.700	172.000	7205002
50	53030-3510	1.000	172.000	7205002
51	53030-3510	0.750	172.000	7205002
52	57030-3548	2.700	210.000	7678699
53	57030-3548	4.500	210.000	7678699
54	57030-3548	0.900	210.000	7678699
55	57030-3548	1.800	210.000	7678699
56	57030-3548	1.800	210.000	7678699
57	57040-3561	0.040	0.427	3734203
58	57040-3561	0.020	0.427	3734203
59	57040-3561	0.070	0.427	3734203
60	57040-3561	0.050	0.427	3734203

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	C1	C2	C3
41	1	0	0	0	0	1	0	0	0	0	1	0	0	0
42	0	0	1	0	0	0	1	0	0	1	0	0	1	0
43	0	0	1	0	0	0	1	0	0	1	0	0	1	0
44	0	0	1	0	0	0	1	0	0	1	0	0	1	0
45	0	0	1	0	0	0	1	0	0	1	0	0	1	0
46	0	0	1	0	0	0	1	0	0	1	0	0	1	0
47	0	0	0	1	0	1	0	0	0	1	0	0	0	1
48	0	0	0	1	0	1	0	0	0	1	0	0	0	1
49	0	0	0	1	0	1	0	0	0	1	0	0	0	1
50	0	0	0	1	0	1	0	0	0	1	0	0	0	1
51	0	0	0	1	0	1	0	0	0	1	0	0	0	1
52	0	0	0	1	0	1	0	0	0	1	0	0	0	1
53	0	0	0	1	0	1	0	0	0	1	0	0	0	1
54	0	0	0	1	0	1	0	0	0	1	0	0	0	1
55	0	0	0	1	0	1	0	0	0	1	0	0	0	1
56	0	0	0	1	0	1	0	0	0	1	0	0	0	1
57	0	0	0	0	0	0	1	0	0	0	1	0	1	0
58	0	0	0	0	0	0	1	0	0	0	1	0	1	0
59	0	0	0	0	0	0	1	0	0	0	1	0	1	0
60	0	0	0	0	0	0	1	0	0	0	1	0	1	0

DATA SET FOR CLEARING AND GRUBBING

OBS	PROJECT NUMBER	PRODUCTION RATE ACRES/DAY	F1	F2
61	57040-3561	0.030	0.427	3734203
62	60580-3603	0.190	2.170	406333
63	60580-3603	0.280	2.170	406333
64	60580-3603	0.560	2.170	406333
65	60580-3603	0.570	2.170	406333
66	60580-3603	0.570	2.170	406333
67	70220-3429	5.000	82.840	4886118
68	70220-3429	4.000	82.840	4886118
69	70220-3429	6.000	82.840	4886118
70	70220-3429	5.000	82.840	4886118
71	70220-3429	5.000	82.840	4886118
72	72002-3529	2.640	56.900	4540541
73	72002-3529	2.700	56.900	4540541
74	72002-3529	0.500	56.900	4540541
75	72002-3529	4.820	56.900	4540541
76	72002-3529	3.550	56.900	4540541
77	78010-3527	0.018	0.036	348638
78	79170-3510	2.400	9.735	563401
79	79170-3510	0.400	9.735	563401
80	79170-3510	1.000	9.735	563401

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	C1	C2	C3
61	0	0	0	0	0	0	1	0	0	0	1	0	1	0
62	1	0	0	0	0	1	0	0	1	0	0	0	0	1
63	1	0	0	0	0	1	0	0	1	0	0	0	0	1
64	1	0	0	0	0	1	0	0	1	0	0	0	0	1
65	1	0	0	0	0	1	0	0	1	0	0	0	0	1
66	1	0	0	0	0	1	0	0	1	0	0	0	0	1
67	0	0	0	0	0	0	0	1	0	1	0	0	0	0
68	0	0	0	0	0	0	0	1	0	1	0	0	0	0
69	0	0	0	0	0	0	0	1	0	1	0	0	0	0
70	0	0	0	0	0	0	0	1	0	1	0	0	0	0
71	0	0	0	0	0	0	0	1	0	1	0	0	0	0
72	0	0	0	1	0	0	0	0	0	0	1	0	0	0
73	0	0	0	1	0	0	0	0	0	0	1	0	0	0
74	0	0	0	1	0	0	0	0	0	0	1	0	0	0
75	0	0	0	1	0	0	0	0	0	0	1	0	0	0
76	0	0	0	1	0	0	0	0	0	0	1	0	0	0
77	0	0	1	0	0	0	1	0	0	0	1	0	0	1
78	1	0	0	0	0	0	1	0	0	0	1	0	1	0
79	1	0	0	0	0	0	1	0	0	0	1	0	1	0
80	1	0	0	0	0	0	1	0	0	0	1	0	1	0

DATA SET FOR CLEARING AND GRUBBING

OBS	PROJECT NUMBER	PRODUCTION RATE ACRES/DAY	F1	F2
81	79190-3505	1.860	14.974	796699
82	79190-3505	2.327	14.974	796699
83	79190-3505	1.571	14.974	796699
84	79190-3505	0.178	14.974	796699
85	79190-3505	0.832	14.974	796699
86	87055-3601	0.400	15.000	1807970
87	87055-3601	0.400	15.000	1807970
88	87055-3601	1.300	15.000	1807970
89	87055-3601	0.300	15.000	1807970
90	87055-3601	0.700	15.000	1807970
91	93060-3542	3.200	16.000	4039137
92	93060-3542	4.500	16.000	4039137
93	93060-3542	1.600	16.000	4039137
94	93060-3542	1.600	16.000	4039137
95	93060-3542	5.100	16.000	4039137
96	93230-3504	0.250	0.250	413419

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	C1	C2	C3
81	1	0	0	0	0	0	1	0	0	0	1	0	1	0
82	1	0	0	0	0	0	1	0	0	0	1	0	1	0
83	1	0	0	0	0	0	1	0	0	0	1	0	1	0
84	1	0	0	0	0	0	1	0	0	0	1	0	1	0
85	1	0	0	0	0	0	1	0	0	0	1	0	1	0
86	1	0	0	0	0	0	1	0	0	0	1	0	1	0
87	1	0	0	0	0	0	1	0	0	0	1	0	1	0
88	1	0	0	0	0	0	1	0	0	0	1	0	1	0
89	1	0	0	0	0	0	1	0	0	0	1	0	1	0
90	1	0	0	0	0	0	1	0	0	0	1	0	1	0
91	1	0	0	0	0	0	1	0	0	1	0	0	0	1
92	1	0	0	0	0	0	1	0	0	1	0	0	0	1
93	1	0	0	0	0	0	1	0	0	1	0	0	0	1
94	1	0	0	0	0	0	1	0	0	1	0	0	0	1
95	1	0	0	0	0	0	1	0	0	1	0	0	0	1
96	1	0	0	0	0	1	0	0	0	1	0	0	1	0

DATA SET FOR EXCAVATION

OBS	PROJECT NUMBER	PRODUCTION RATE CY/DAY	F1	F2
1	02010-3532	81.00	2838	177625.00
2	02010-3532	88.00	2838	177625.00
3	02010-3532	77.00	2838	177625.00
4	02010-3532	750.00	2838	177625.00
5	02010-3532	700.00	2838	177625.00
6	10020-3513	734.00	100930	3185151.00
7	10020-3513	489.00	100930	3185151.00
8	10020-3513	1899.00	100930	3185151.00
9	10020-3513	1675.00	100930	3185151.00
10	10020-3513	178.00	100930	3185151.00
11	10160-3525	2193.00	13525	4319100.35
12	10160-3525	2856.00	13525	4319100.35
13	10160-3525	2482.00	13525	4319100.35
14	10160-3525	1156.00	13525	4319100.35
15	10160-3525	1989.00	13525	4319100.35
16	11140-3507	491.00	5843	345775.00
17	11140-3507	533.00	5843	345775.00
18	11140-3507	619.00	5843	345775.00
19	11140-3507	491.00	5843	345775.00
20	11140-3507	85.00	5843	345775.00

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	E1	E2	E3	E4	E5	E6
1	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
2	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
3	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
4	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
5	1	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
6	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
7	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
8	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
9	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
10	0	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
11	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0
12	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0
13	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0
14	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0
15	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0
16	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
17	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
18	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
19	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
20	1	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0

DATA SET FOR EXCAVATION

OBS	PROJECT NUMBER	PRODUCTION RATE CY/DAY	F1	F2	F3
21	12005-3507	91.30	1568	339858	0
22	12005-3507	457.70	1568	339858	0
23	12005-3507	13.23	1568	339858	0
24	12005-3507	138.09	1568	339858	0
25	12005-3507	233.19	1568	339858	0
26	12020-3534	142.00	829	1369359	1
27	12020-3534	130.00	829	1369359	1
28	30030-3506	1386.00	75118	1465504	1
29	30030-3506	1964.00	75118	1465504	1
30	30030-3506	1895.00	75118	1465504	1
31	30030-3506	2114.00	75118	1465504	1
32	30030-3506	1583.00	75118	1465504	1
33	35350-3502	2061.00	7341	2997476	0
34	35350-3502	397.00	7341	2997476	0
35	35350-3502	323.00	7341	2997476	0
36	35350-3502	459.00	7341	2997476	0
37	35350-3502	527.00	7341	2997476	0
38	36570-3605	124.00	646	143684	0
39	36570-3605	124.00	646	143684	0
40	36570-3605	62.00	646	143684	0

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	E1	E2	E3	E4	E5	E6
21	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0
22	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0
23	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0
24	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0
25	0	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0
26	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0
27	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1
28	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0
29	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0
30	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0
31	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0
32	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0
33	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
34	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
35	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
36	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
37	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0
38	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
39	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
40	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0

DATA SET FOR EXCAVATION

OBS	PROJECT NUMBER	PRODUCTION RATE CY/DAY	F1	F2	F3
41	36570-3605	124.00	646	143684	0
42	36570-3605	62.00	646	143684	0
43	46040-3545	773.00	773	182576	0
44	48060-3506	1000.00	268142	4026596	1
45	48060-3506	500.00	268142	4026596	1
46	48060-3506	500.00	268142	4026596	1
47	48060-3506	1000.00	268142	4026596	1
48	48731-3604	202.00	404	209372	0
49	48731-3604	100.00	404	209372	0
50	48731-3604	100.00	404	209372	0
51	53030-3510	2100.00	28680	7205002	0
52	53030-3510	1980.00	28680	7205002	0
53	53030-3510	2200.00	28680	7205002	0
54	53030-3510	700.00	28680	7205002	0
55	53030-3510	3800.00	28680	7205002	0
56	55020-3519	23.34	231	235512	1
57	55020-3519	11.67	231	235512	1
58	55020-3519	58.47	231	235512	1
59	55020-3519	46.00	231	235512	1
60	55020-3519	91.52	231	235512	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	E1	E2	E3	E4	E5	E6
41	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
42	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
43	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0
44	0	0	0	0	1	0	0	0	0	1	1	0	0	1	0	0
45	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
46	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
47	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
48	0	1	0	0	0	1	0	0	1	0	1	0	0	1	0	0
49	0	1	0	0	0	1	0	0	1	0	1	0	0	1	0	0
50	0	1	0	0	0	1	0	0	1	0	1	0	0	1	0	0
51	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0
52	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0
53	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0
54	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0
55	0	0	1	0	1	0	0	0	1	0	1	0	0	0	0	0
56	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
57	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
58	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
59	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
60	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0

DATA SET FOR EXCAVATION

OBS	PROJECT NUMBER	PRODUCTION RATE CY/DAY	F1	F2	F3
61	55040-3525	361.68	4435	1194647	1
62	55040-3525	287.22	4435	1194647	1
63	55040-3525	368.64	4435	1194647	1
64	55040-3525	361.69	4435	1194647	1
65	55040-3525	289.18	4435	1194647	1
66	57030-3548	2000.00	310101	7678699	0
67	57030-3548	12451.00	310101	7678699	0
68	57030-3548	4981.00	310101	7678699	0
69	57030-3548	4981.00	310101	7678699	0
70	57030-3548	7332.00	310101	7678699	0
71	57040-3558	88.00	8331	3954939	1
72	57040-3558	159.00	8331	3954939	1
73	57040-3558	547.00	8331	3954939	1
74	57040-3558	60.00	8331	3954939	1
75	57040-3558	217.00	8331	3954939	1
76	57080-3505	602.00	18514	1277510	1
77	57080-3505	1095.00	18514	1277510	1
78	57080-3505	717.00	18514	1277510	1
79	57080-3505	496.00	18514	1277510	1
80	57080-3505	556.00	18514	1277510	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	E1	E2	E3	E4	E5	E6
61	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
62	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
63	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
64	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
65	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
66	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
67	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
68	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
69	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
70	0	0	1	0	1	0	0	0	1	0	1	0	0	1	0	0
71	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
72	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
73	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
74	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
75	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
76	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0
77	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0
78	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0
79	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0
80	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0

DATA SET FOR EXCAVATION

OBS	PROJECT NUMBER	PRODUCTION RATE CY/DAY	F1	F2	F3
81	61080-3524	1238.00	19724	1859693	1
82	61080-3524	1405.00	19724	1859693	1
83	61080-3524	1539.13	19724	1859693	1
84	61080-3524	1322.00	19724	1859693	1
85	61080-3524	1372.00	19724	1859693	1
86	72002-3529	1530.00	91106	4540541	0
87	72002-3529	750.00	91106	4540541	0
88	72002-3529	1185.00	91106	4540541	0
89	72002-3529	1785.00	91106	4540541	0
90	72002-3529	1580.00	91106	4540541	0
91	76020-3518	127.00	6899	527986	1
92	76020-3518	650.00	6899	527986	1
93	78010-3527	6.63	1312	348638	0
94	78010-3527	7.30	1312	348638	0
95	79170-3510	94.00	11134	563401	1
96	79170-3510	53.00	11134	563401	1
97	79170-3510	1111.00	11134	563401	1
98	79170-3510	724.00	11134	563401	1
99	79170-3510	.	11134	563401	1
100	79190-3505	227.20	3471	796699	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	E1	E2	E3	E4	E5	E6
81	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1
82	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1
83	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1
84	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1
85	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1
86	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0
87	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0
88	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0
89	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0
90	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0
91	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0
92	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0
93	0	1	0	0	0	1	0	0	0	1	1	0	0	1	0	0
94	0	1	0	0	0	1	0	0	0	1	1	0	0	1	0	0
95	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
96	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
97	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
98	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
99	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
100	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0

DATA SET FOR EXCAVATION

OBS	PROJECT NUMBER	PRODUCTION RATE CY/DAY	F1	F2	F3
101	79190-3505	374.37	3471	796699	1
102	79190-3505	1116.90	3471	796699	1
103	79190-3505	36.88	3471	796699	1
104	79210-3501	40.90	2185	392641	1
105	79210-3501	319.90	2185	392641	1
106	79210-3501	428.30	2185	392641	1
107	79210-3501	239.90	2185	392641	1
108	79210-3501	319.90	2185	392641	1
109	87055-3601	1400.00	16263	1807970	1
110	87055-3601	1700.00	16263	1807970	1
111	87055-3601	1000.00	16263	1807970	1
112	87055-3601	600.00	16263	1807970	1
113	87055-3601	600.00	16263	1807970	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	E1	E2	E3	E4	E5	E6
101	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
102	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
103	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
104	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0
105	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0
106	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0
107	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0
108	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0
109	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
110	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
111	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
112	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0
113	0	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0

DATA SET FOR BASE

OBS	PROJECT NUMBER	PRODUCTION RATE SY/DAY	F1	F2
1	02010-3517	1024.00	14793	.
2	02010-3523	1024.00	14793	3132002.00
3	02010-3532	182.00	1590	177625.00
4	02010-3532	294.00	1590	177625.00
5	02010-3532	146.00	1590	177625.00
6	02010-3532	40.00	1590	177625.00
7	02010-3532	889.00	1590	177625.00
8	10020-3513	1293.00	101185	3185151.00
9	10020-3513	1053.00	101185	3185151.00
10	10020-3513	1038.00	101185	3185151.00
11	10020-3513	1346.00	101185	3185151.00
12	10020-3513	388.00	101185	3185151.00
13	10160-3525	4000.00	109793	4319100.35
14	10160-3525	2400.00	109793	4319100.35
15	10160-3525	6400.00	109793	4319100.35
16	10160-3525	4400.00	109793	4319100.35
17	10160-3525	6000.00	109793	4319100.35
18	12005-3507	328.50	4243	339858.00
19	12005-3507	363.60	4243	339858.00
20	12005-3507	680.86	4243	339858.00

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	B1	B2	B3
1	.	.	.	.	.	.	.	.	.	.	0	0	0	0
2	0	1	0	0	0	0	1	0	0	1	0	0	1	0
3	1	0	0	0	0	0	1	0	0	0	1	0	1	0
4	1	0	0	0	0	0	1	0	0	0	1	0	1	0
5	1	0	0	0	0	0	1	0	0	0	1	0	1	0
6	1	0	0	0	0	0	1	0	0	0	1	0	1	0
7	1	0	0	0	0	0	1	0	0	0	1	0	1	0
8	0	0	0	1	0	1	0	0	0	1	0	0	1	0
9	0	0	0	1	0	1	0	0	0	1	0	0	1	0
10	0	0	0	1	0	1	0	0	0	1	0	0	1	0
11	0	0	0	1	0	1	0	0	0	1	0	0	1	0
12	0	0	0	1	0	1	0	0	0	1	0	0	1	0
13	0	0	0	1	0	0	1	0	0	0	1	0	1	0
14	0	0	0	1	0	0	1	0	0	0	1	0	1	0
15	0	0	0	1	0	0	1	0	0	0	1	0	1	0
16	0	0	0	1	0	0	1	0	0	0	1	0	1	0
17	0	0	0	1	0	0	1	0	0	0	1	0	1	0
18	0	0	0	0	1	0	1	0	0	0	1	0	0	1
19	0	0	0	0	1	0	1	0	0	0	1	0	0	1
20	0	0	0	0	1	0	1	0	0	0	1	0	0	1

DATA SET FOR BASE

OBS	PROJECT NUMBER	PRODUCTION RATE SY/DAY	F1	F2
21	12005-3507	180.45	4243	339858
22	12005-3507	153.74	4243	339858
23	12020-3534	91.00	.	1369359
24	12020-3534	227.00	.	1369359
25	16510-3605	2501.00	26192	1250680
26	16510-3605	2889.00	26192	1250680
27	16510-3605	10923.00	26192	1250680
28	16510-3605	3326.00	26192	1250680
29	16510-3605	6556.00	26192	1250680
30	30030-3506	2389.00	19391	1465504
31	30030-3506	2716.00	19391	1465504
32	30030-3506	2323.00	19391	1465504
33	30030-3506	1908.00	19391	1465504
34	30030-3506	2120.00	19391	1465504
35	35010-3513	2409.00	22960	2322152
36	35050-3507	1794.00	58524	1646955
37	35050-3507	1794.00	58524	1646955
38	35050-3507	2172.00	58524	1646955
39	35050-3507	1936.00	58524	1646955
40	35050-3507	992.00	58524	1646955

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	B1	B2	B3
21	0	0	0	0	1	0	1	0	0	0	1	0	0	1
22	0	0	0	0	1	0	1	0	0	0	1	0	0	1
23	1	0	0	0	0	0	1	0	0	0	1	0	0	1
24	1	0	0	0	0	0	1	0	0	0	1	0	0	1
25	1	0	0	0	0	1	0	0	0	1	0	0	0	1
26	1	0	0	0	0	1	0	0	0	1	0	0	0	1
27	1	0	0	0	0	1	0	0	0	1	0	0	0	1
28	1	0	0	0	0	1	0	0	0	1	0	0	0	1
29	1	0	0	0	0	1	0	0	0	1	0	0	0	1
30	1	0	0	0	0	1	0	0	0	1	0	0	0	1
31	1	0	0	0	0	1	0	0	1	0	0	0	1	0
32	1	0	0	0	0	1	0	0	1	0	0	0	1	0
33	1	0	0	0	0	1	0	0	1	0	0	0	1	0
34	1	0	0	0	0	1	0	0	1	0	0	0	1	0
35	0	1	0	0	0	1	0	0	0	1	0	0	1	0
36	1	0	0	0	0	1	0	0	0	1	0	0	1	0
37	1	0	0	0	0	1	0	0	0	1	0	0	1	0
38	1	0	0	0	0	1	0	0	0	1	0	0	1	0
39	1	0	0	0	0	1	0	0	0	1	0	0	1	0
40	1	0	0	0	0	1	0	0	0	1	0	0	1	0

DATA SET FOR BASE

OBS	PROJECT NUMBER	PRODUCTION RATE SY/DAY	F1	F2
41	35350-3502	2844.00	19961	2997476
42	35350-3502	333.00	19961	2997476
43	35350-3502	1422.00	19961	2997476
44	35350-3502	1011.00	19961	2997476
45	35350-3502	127.00	19961	2997476
46	36060-3517	1024.00	.	.
47	36060-3517	1024.00	.	.
48	36060-3517	1024.00	.	.
49	36570-3605	253.00	4706	143684
50	36570-3605	353.00	4706	143684
51	36570-3605	232.00	4706	143684
52	36570-3605	174.00	4706	143684
53	36570-3605	140.00	4706	143684
54	37010-3512	2250.00	22960	.
55	37010-3512	2600.00	22960	.
56	37010-3512	2900.00	22960	.
57	37010-3512	1980.00	22960	.
58	46040-3545	903.00	1188	182576
59	46040-3545	97.00	1188	182576
60	48060-3506	1139.00	87098	4026596

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	B1	B2	B3
41	0	0	0	1	0	1	0	0	0	0	1	0	1	0
42	0	0	0	1	0	1	0	0	0	0	1	0	1	0
43	0	0	0	1	0	1	0	0	0	0	1	0	1	0
44	0	0	0	1	0	1	0	0	0	0	1	0	1	0
45	0	0	0	1	0	1	0	0	0	0	1	0	1	0
46	.	.	.	.	.	.	.	.	.	.	0	0	0	0
47	.	.	.	.	.	.	.	.	.	.	0	0	0	0
48	.	.	.	.	.	.	.	.	.	.	0	0	0	0
49	0	0	1	0	0	1	0	0	1	0	0	0	1	0
50	0	0	1	0	0	1	0	0	1	0	0	0	1	0
51	0	0	1	0	0	1	0	0	1	0	0	0	1	0
52	0	0	1	0	0	1	0	0	1	0	0	0	1	0
53	0	0	1	0	0	1	0	0	1	0	0	0	1	0
54	.	.	.	.	.	.	.	.	.	.	0	0	1	0
55	.	.	.	.	.	.	.	.	.	.	0	0	1	0
56	.	.	.	.	.	.	.	.	.	.	0	0	1	0
57	.	.	.	.	.	.	.	.	.	.	0	0	1	0
58	0	0	0	0	0	0	0	0	0	0	1	0	0	1
59	0	0	0	0	0	0	0	0	0	0	1	0	0	1
60	1	0	0	0	0	1	0	0	0	0	1	0	0	0

DATA SET FOR BASE

OBS	PROJECT NUMBER	PRODUCTION RATE SY/DAY	F1	F2
61	48060-3506	2314.00	87098	4026596
62	48060-3506	4789.00	87098	4026596
63	48060-3506	1634.00	87098	4026596
64	48060-3506	3675.00	87098	4026596
65	48731-3604	306.00	1823	209372
66	48731-3604	338.00	1823	209372
67	48731-3604	152.00	1823	209372
68	48731-3604	485.00	1823	209372
69	53030-3510	168.00	275165	7205002
70	53030-3510	78.00	275165	7205002
71	53030-3510	2000.00	275165	7205002
72	53030-3510	2635.00	275165	7205002
73	53030-3510	2234.00	275165	7205002
74	55020-3519	55.00	588	235512
75	55020-3519	55.00	588	235512
76	55020-3519	163.00	588	235512
77	55020-3519	130.00	588	235512
78	55020-3519	184.46	588	235512
79	55040-3525	3117.00	44089	1194647
80	55040-3525	4500.00	44089	1194647

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	B1	B2	B3
61	1	0	0	0	0	1	0	0	0	0	1	0	0	0
62	1	0	0	0	0	1	0	0	0	0	1	0	0	0
63	1	0	0	0	0	1	0	0	0	0	1	0	0	0
64	1	0	0	0	0	1	0	0	0	0	1	0	0	0
65	0	0	1	0	0	0	1	0	0	1	0	0	0	1
66	0	0	1	0	0	0	1	0	0	1	0	0	0	1
67	0	0	1	0	0	0	1	0	0	1	0	0	0	1
68	0	0	1	0	0	0	1	0	0	1	0	0	0	1
69	0	0	0	1	0	1	0	0	0	1	0	0	1	0
70	0	0	0	1	0	1	0	0	0	1	0	0	1	0
71	0	0	0	1	0	1	0	0	0	1	0	0	1	0
72	0	0	0	1	0	1	0	0	0	1	0	0	1	0
73	0	0	0	1	0	1	0	0	0	1	0	0	1	0
74	1	0	0	0	0	0	1	0	0	0	1	0	1	0
75	1	0	0	0	0	0	1	0	0	0	1	0	1	0
76	1	0	0	0	0	0	1	0	0	0	1	0	1	0
77	1	0	0	0	0	0	1	0	0	0	1	0	1	0
78	1	0	0	0	0	0	1	0	0	0	1	0	1	0
79	1	0	0	0	0	0	0	0	0	0	0	0	1	0
80	1	0	0	0	0	0	0	0	0	0	0	0	1	0

DATA SET FOR BASE

OBS	PROJECT NUMBER	PRODUCTION RATE SY/DAY	F1	F2
81	55040-3525	930.00	44089.0	1194647
82	55040-3525	5950.00	44089.0	1194647
83	55040-3525	3300.00	44089.0	1194647
84	55080-3532	1794.00	40854.0	2163817
85	55080-3532	3987.00	40854.0	2163817
86	55080-3532	4746.00	40854.0	2163817
87	55080-3532	3778.00	40854.0	2163817
88	55080-3532	2503.00	40854.0	2163817
89	57030-3548	917.00	236916.0	7678699
90	57040-3558	70.00	9765.0	3954939
91	57040-3558	91.00	9765.0	3954939
92	57040-3558	261.00	9765.0	3954939
93	57040-3558	175.00	9765.0	3954939
94	57040-3558	49.00	9765.0	3954939
95	57080-3505	3584.00	18599.0	1277510
96	57080-3505	3665.00	18599.0	1277510
97	57080-3505	2213.00	18599.0	1277510
98	57080-3505	3169.00	18599.0	1277510
99	57080-3505	2997.00	18599.0	1277510
100	58050-3514	2306.00	36594.0	2444275

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	B1	B2	B3
81	1	0	0	0	0	0	0	0	0	0	0	0	1	0
82	1	0	0	0	0	0	0	0	0	0	0	0	1	0
83	1	0	0	0	0	0	0	0	0	0	0	0	1	0
84	1	0	0	0	0	1	0	0	0	1	0	1	0	0
85	1	0	0	0	0	1	0	0	0	1	0	1	0	0
86	1	0	0	0	0	1	0	0	0	1	0	1	0	0
87	1	0	0	0	0	1	0	0	0	1	0	1	0	0
88	1	0	0	0	0	1	0	0	0	1	0	1	0	0
89	0	0	0	1	0	1	0	0	0	1	0	0	0	0
90	1	0	0	0	0	0	1	0	0	0	1	0	0	1
91	1	0	0	0	0	0	1	0	0	0	1	0	0	1
92	1	0	0	0	0	0	1	0	0	0	1	0	0	1
93	1	0	0	0	0	0	1	0	0	0	1	0	0	1
94	1	0	0	0	0	0	1	0	0	0	1	0	0	1
95	1	0	0	0	0	1	0	0	0	1	0	0	0	1
96	1	0	0	0	0	1	0	0	0	1	0	0	0	1
97	1	0	0	0	0	1	0	0	0	1	0	0	0	1
98	1	0	0	0	0	1	0	0	0	1	0	0	0	1
99	1	0	0	0	0	1	0	0	0	1	0	0	0	1
100	1	0	0	0	0	1	0	0	0	1	0	0	0	1

DATA SET FOR BASE

OBS	PROJECT NUMBER	PRODUCTION RATE SY/DAY	F1	F2
101	58050-3514	2396.00	36594.0	2444275
102	58050-3514	798.00	36594.0	2444275
103	58050-3514	2665.00	36594.0	2444275
104	58050-3514	1344.00	36594.0	2444275
105	60020-3504	900.00	.	.
106	60020-3504	837.00	.	.
107	60020-3504	3426.00	.	.
108	60020-3504	455.00	.	.
109	61086-3522	76.44	79.0	330043
110	70100-3547	918.00	20171.0	364027
111	70100-3547	1317.00	20171.0	364027
112	70100-3547	2488.00	20171.0	364027
113	70100-3547	2420.00	20171.0	364027
114	72160-3551	2000.00	113000.0	4016077
115	72160-3551	2011.00	113000.0	4016077
116	72160-3551	1331.00	113000.0	4016077
117	72160-3551	1331.00	113000.0	4016077
118	72160-3551	1331.00	113000.0	4016077
119	72160-3551	1331.00	113000.0	4016077
120	76000-3608	906.00	4244.8	523676

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	B1	B2	B3
101	1	0	0	0	0	1	0	0	0	1	0	0	0	1
102	1	0	0	0	0	1	0	0	0	1	0	0	0	1
103	1	0	0	0	0	1	0	0	0	1	0	0	0	1
104	1	0	0	0	0	1	0	0	0	1	0	0	0	1
105	.	.	.	.	.	.	.	.	.	.	0	0	0	0
106	.	.	.	.	.	.	.	.	.	.	0	0	0	0
107	.	.	.	.	.	.	.	.	.	.	0	0	0	0
108	.	.	.	.	.	.	.	.	.	.	0	0	0	0
109	1	0	0	0	0	0	1	0	0	1	0	0	0	1
110	1	0	0	0	0	0	1	0	0	0	1	0	0	1
111	1	0	0	0	0	0	1	0	0	0	1	0	0	1
112	1	0	0	0	0	0	1	0	0	0	1	0	0	1
113	1	0	0	0	0	0	1	0	0	0	1	0	0	1
114	1	0	0	0	0	0	1	0	0	0	1	0	1	0
115	1	0	0	0	0	0	1	0	0	0	1	0	1	0
116	1	0	0	0	0	0	1	0	0	0	1	0	1	0
117	1	0	0	0	0	0	1	0	0	0	1	0	1	0
118	1	0	0	0	0	0	1	0	0	0	1	0	1	0
119	1	0	0	0	0	0	1	0	0	0	1	0	1	0
120	1	0	0	0	0	1	0	0	1	0	0	0	1	0

DATA SET FOR BASE

OBS	PROJECT NUMBER	PRODUCTION RATE SY/DAY	F1	F2
121	76000-3608	1000.00	4244.8	523676
122	76000-3608	1000.00	4244.8	523676
123	76020-3518	14.40	4189.0	527986
124	78010-3527	177.20	.	348638
125	78010-3527	135.90	.	348638
126	78010-3527	97.20	.	348638
127	78010-3527	49.90	.	348638
128	78040-3528	30.00	70448.0	3558455
129	78040-3528	30.00	70448.0	3558455
130	78040-3528	30.00	70448.0	3558455
131	78040-3528	30.00	70448.0	3558455
132	78040-3528	30.00	70448.0	3558455
133	79170-3510	178.00	10496.0	563401
134	79170-3510	734.00	10496.0	563401
135	79170-3510	867.00	10496.0	563401
136	79170-3510	219.00	10496.0	563401
137	79190-3505	700.30	8755.0	796699
138	79190-3505	1237.50	8755.0	796699
139	79190-3505	444.10	8755.0	796699
140	79190-3505	373.45	8755.0	796699

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	B1	B2	B3
121	1	0	0	0	0	1	0	0	1	0	0	0	1	0
122	1	0	0	0	0	1	0	0	1	0	0	0	1	0
123	1	0	0	0	0	0	1	0	0	0	1	0	1	0
124	0	0	1	0	0	0	1	0	0	0	1	0	1	0
125	0	0	1	0	0	0	1	0	0	0	1	0	0	1
126	0	0	1	0	0	0	1	0	0	0	1	0	0	1
127	0	0	1	0	0	0	1	0	0	0	1	0	0	1
128	1	0	0	0	0	0	1	0	0	0	1	0	1	0
129	1	0	0	0	0	0	1	0	0	0	1	0	1	0
130	1	0	0	0	0	0	1	0	0	0	1	0	1	0
131	1	0	0	0	0	0	1	0	0	0	1	0	1	0
132	1	0	0	0	0	0	1	0	0	0	1	0	1	0
133	1	0	0	0	0	0	1	0	0	0	1	0	1	0
134	1	0	0	0	0	0	1	0	0	0	1	0	1	0
135	1	0	0	0	0	0	1	0	0	0	1	0	1	0
136	1	0	0	0	0	0	1	0	0	0	1	0	1	0
137	1	0	0	0	0	0	1	0	0	0	1	0	1	0
138	1	0	0	0	0	0	1	0	0	0	1	0	1	0
139	1	0	0	0	0	0	1	0	0	0	1	0	1	0
140	1	0	0	0	0	0	1	0	0	0	1	0	1	0

DATA SET FOR BASE

OBS	PROJECT NUMBER	PRODUCTION RATE SY/DAY	F1	F2
141	79190-3505	1581.00	8755.0	796699
142	87055-3601	920.00	47650.0	1807970
143	87055-3601	2000.00	47650.0	1807970
144	87055-3601	2200.00	47650.0	1807970
145	87055-3601	1200.00	47650.0	1807970
146	87055-3601	1300.00	47650.0	1807970
147	93060-3542	1760.00	5293.0	4039137
148	93060-3542	3533.00	5293.0	4039137
149	93230-3504	1062.50	5973.0	413419
150	93230-3504	3768.60	5973.0	413419
151	93230-3504	802.50	5973.0	413419

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	B1	B2	B3
141	1	0	0	0	0	0	1	0	0	0	1	0	1	0
142	1	0	0	0	0	0	1	0	0	0	1	0	1	0
143	1	0	0	0	0	0	1	0	0	0	1	0	1	0
144	1	0	0	0	0	0	1	0	0	0	1	0	1	0
145	1	0	0	0	0	0	1	0	0	0	1	0	1	0
146	1	0	0	0	0	0	1	0	0	0	1	0	1	0
147	1	0	0	0	0	0	1	0	0	1	0	0	0	1
148	1	0	0	0	0	0	1	0	0	1	0	0	0	1
149	1	0	0	0	0	1	0	0	0	1	0	0	0	1
150	1	0	0	0	0	1	0	0	0	1	0	0	0	1
151	1	0	0	0	0	1	0	0	0	1	0	0	0	1

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2
1	02010-3532	233.30	400.00	177625.00
2	02010-3532	217.60	400.00	177625.00
3	02010-3532	143.51	400.00	177625.00
4	02010-3532	90.62	400.00	177625.00
5	09030-3520	1165.82	22775.50	1498587.00
6	09030-3520	1310.29	22775.50	1498587.00
7	09030-3520	697.75	22775.50	1498587.00
8	09030-3520	951.83	22775.50	1498587.00
9	09030-3520	929.96	22775.50	1498587.00
10	09060-3512	606.24	46595.00	2853579.00
11	09060-3512	1076.38	46595.00	2853579.00
12	09060-3512	937.95	46595.00	2853579.00
13	09060-3512	811.55	46595.00	2853579.00
14	09060-3512	1109.18	46595.00	2853579.00
15	10020-3513	196.10	99793.00	3185151.00
16	10020-3513	151.40	99793.00	3185151.00
17	10020-3513	291.20	99793.00	3185151.00
18	10020-3513	700.00	99793.00	3185151.00
19	10160-3525	200.54	4109.40	4319100.35
20	10160-3525	337.08	4109.40	4319100.35

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
1	1	0	0	0	0	0	1	0	0	0	1	0
2	1	0	0	0	0	0	1	0	0	0	1	0
3	1	0	0	0	0	0	1	0	0	0	1	0
4	1	0	0	0	0	0	1	0	0	0	1	0
5	1	0	0	0	0	1	0	0	0	0	1	0
6	1	0	0	0	0	1	0	0	0	0	1	0
7	1	0	0	0	0	1	0	0	0	0	1	0
8	1	0	0	0	0	1	0	0	0	0	1	0
9	1	0	0	0	0	1	0	0	0	0	1	0
10	1	0	0	0	0	1	0	0	0	1	0	1
11	1	0	0	0	0	1	0	0	0	1	0	1
12	1	0	0	0	0	1	0	0	0	1	0	1
13	1	0	0	0	0	1	0	0	0	1	0	1
14	1	0	0	0	0	1	0	0	0	1	0	1
15	0	0	0	1	0	1	0	0	0	1	0	0
16	0	0	0	1	0	1	0	0	0	1	0	0
17	0	0	0	1	0	1	0	0	0	1	0	0
18	0	0	0	1	0	1	0	0	0	1	0	0
19	0	0	0	1	0	0	1	0	0	0	1	1
20	0	0	0	1	0	0	1	0	0	0	1	1

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2
21	10160-3525	117.06	4109.40	4319100.35
22	10160-3525	247.20	4109.40	4319100.35
23	10160-3525	171.82	4109.40	4319100.35
24	11140-3507	370.59	3513.30	345775.00
25	11140-3507	231.75	3513.30	345775.00
26	11140-3507	553.74	3513.30	345775.00
27	11140-3507	497.06	3513.30	345775.00
28	11140-3507	732.44	3513.30	345775.00
29	29180-3442	581.63	38651.00	1570359.00
30	29180-3442	1072.57	38651.00	1570359.00
31	29180-3442	1201.13	38651.00	1570359.00
32	29180-3442	1068.92	38651.00	1570359.00
33	29180-3442	1246.91	38651.00	1570359.00
34	30030-3506	2045.90	20022.00	1465504.00
35	30030-3506	1136.30	20022.00	1465504.00
36	30030-3506	1402.40	20022.00	1465504.00
37	30030-3506	1295.10	20022.00	1465504.00
38	30030-3506	1535.90	20022.00	1465504.00
39	34010-3526	1345.00	35734.00	1539380.00
40	34010-3526	1602.00	35734.00	1539380.00

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
21	0	0	0	1	0	0	1	0	0	0	1	1
22	0	0	0	1	0	0	1	0	0	0	1	1
23	0	0	0	1	0	0	1	0	0	0	1	1
24	1	0	0	0	0	0	0	0	0	1	0	1
25	1	0	0	0	0	0	0	0	0	1	0	1
26	1	0	0	0	0	0	0	0	0	1	0	1
27	1	0	0	0	0	0	0	0	0	1	0	1
28	1	0	0	0	0	0	0	0	0	1	0	1
29	1	0	0	0	0	0	0	1	0	0	1	0
30	1	0	0	0	0	0	0	1	0	0	1	0
31	1	0	0	0	0	0	0	1	0	0	1	0
32	1	0	0	0	0	0	0	1	0	0	1	0
33	1	0	0	0	0	0	0	1	0	0	1	0
34	1	0	0	0	0	1	0	0	1	0	0	0
35	1	0	0	0	0	1	0	0	1	0	0	0
36	1	0	0	0	0	1	0	0	1	0	0	0
37	1	0	0	0	0	1	0	0	1	0	0	0
38	1	0	0	0	0	1	0	0	1	0	0	0
39	1	0	0	0	0	1	0	0	0	1	0	0
40	1	0	0	0	0	1	0	0	0	1	0	0

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2	F3
41	34010-3526	1433.00	35734.00	1539380	1
42	34010-3526	1307.00	35734.00	1539380	1
43	34010-3526	1242.00	35734.00	1539380	1
44	35010-3513	720.45	1705.28	2322152	0
45	35010-3513	533.40	.	2322152	0
46	35010-3513	1309.00	.	2322152	0
47	35050-3507	648.62	40003.00	1646955	1
48	35050-3507	1325.04	40003.00	1646955	1
49	35050-3507	1580.30	40003.00	1646955	1
50	35050-3507	1824.63	40003.00	1646955	1
51	35050-3507	2103.89	40003.00	1646955	1
52	35350-3502	386.00	.	2997476	0
53	35350-3502	620.00	.	2997476	0
54	35350-3502	290.00	.	2997476	0
55	35350-3502	209.00	.	2997476	0
56	35350-3502	114.00	.	2997476	0
57	36570-3605	292.25	1095.51	143684	0
58	36570-3605	355.63	1095.51	143684	0
59	36570-3605	155.07	1095.51	143684	0
60	36570-3605	292.56	1095.51	143684	0

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
41	0	0	0	0	1	0	0	0	1	0	0
42	0	0	0	0	1	0	0	0	1	0	0
43	0	0	0	0	1	0	0	0	1	0	0
44	1	0	0	0	1	0	0	0	1	0	0
45	1	0	0	0	1	0	0	0	1	0	0
46	1	0	0	0	1	0	0	0	1	0	0
47	0	0	0	0	1	0	0	0	1	0	0
48	0	0	0	0	1	0	0	0	1	0	0
49	0	0	0	0	1	0	0	0	1	0	0
50	0	0	0	0	1	0	0	0	1	0	0
51	0	0	0	0	1	0	0	0	1	0	0
52	0	0	1	0	1	0	0	0	0	1	0
53	0	0	1	0	1	0	0	0	0	1	0
54	0	0	1	0	1	0	0	0	0	1	0
55	0	0	1	0	1	0	0	0	0	1	0
56	0	0	1	0	1	0	0	0	0	1	0
57	0	1	0	0	1	0	0	1	0	0	1
58	0	1	0	0	1	0	0	1	0	0	1
59	0	1	0	0	1	0	0	1	0	0	1
60	0	1	0	0	1	0	0	1	0	0	0

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2	F3
61	46040-3545	10.08	133.50	182576	0
62	46040-3545	80.51	133.50	182576	0
63	46040-3545	40.33	133.50	182576	0
64	48060-3506	16.12	284.93	4026596	1
65	48060-3506	84.30	284.93	4026596	1
66	48060-3506	178.65	284.93	4026596	1
67	48060-3506	5.85	284.93	4026596	1
68	48731-3604	22.00	290.88	209372	0
69	48731-3604	105.00	290.88	209372	0
70	48731-3604	147.00	290.88	209372	0
71	48731-3604	17.00	290.88	209372	0
72	5060-3510	560.45	13927.00	1713257	1
73	5060-3510	451.10	.	1713257	1
74	5060-3510	1840.78	.	1713257	1
75	5060-3510	1604.19	.	1713257	1
76	5060-3510	725.24	.	1713257	1
77	53030-3510	4555.00	281653.00	7205002	0
78	53030-3510	7951.00	281653.00	7205002	0
79	53030-3510	11442.00	281653.00	7205002	0
80	53030-3510	8410.00	281653.00	7205002	0

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
61	0	0	0	0	0	0	0	0	0	1	0
62	0	0	0	0	0	0	0	0	0	1	0
63	0	0	0	0	0	0	0	0	0	1	0
64	0	0	0	0	1	0	0	0	0	1	0
65	0	0	0	0	1	0	0	0	0	1	0
66	0	0	0	0	1	0	0	0	0	1	0
67	0	0	0	0	1	0	0	0	0	1	0
68	0	1	0	0	0	1	0	0	1	0	0
69	0	1	0	0	0	1	0	0	1	0	0
70	0	1	0	0	0	1	0	0	1	0	0
71	0	1	0	0	0	1	0	0	1	0	0
72	0	0	0	0	1	0	0	1	0	0	0
73	0	0	0	0	1	0	0	1	0	0	0
74	0	0	0	0	1	0	0	1	0	0	0
75	0	0	0	0	1	0	0	1	0	0	0
76	0	0	0	0	1	0	0	1	0	0	0
77	0	0	1	0	1	0	0	0	1	0	0
78	0	0	1	0	1	0	0	0	1	0	0
79	0	0	1	0	1	0	0	0	1	0	0
80	0	0	1	0	1	0	0	0	1	0	0

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2	F3
81	53030-3510	3229.00	281653.00	7205002	0
82	55020-3519	341.58	937.44	235512	1
83	55020-3519	462.52	937.44	235512	1
84	55020-3519	133.34	937.44	235512	1
85	55040-3525	996.24	9149.30	1194647	1
86	55080-3532	700.24	14906.00	2163817	1
87	55080-3532	1060.48	14906.00	2163817	1
88	55080-3532	1080.09	14906.00	2163817	1
89	55080-3532	1162.00	14906.00	2163817	1
90	55080-3532	1183.93	14906.00	2163817	1
91	57030-3548	812.00	46546.00	7678699	0
92	57030-3548	200.00	.	7678699	0
93	57030-3548	2863.00	.	7678699	0
94	57030-3548	2038.00	.	7678699	0
95	57030-3548	1639.00	.	7678699	0
96	57040-3558	430.00	25379.00	3954939	1
97	57040-3558	806.00	25379.00	3954939	1
98	57040-3558	955.00	25379.00	3954939	1
99	57040-3558	943.00	25379.00	3954939	1
100	57040-3558	610.00	25379.00	3954939	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
81	0	0	1	0	1	0	0	0	1	0	0
82	0	0	0	0	0	1	0	0	0	1	0
83	0	0	0	0	0	1	0	0	0	1	0
84	0	0	0	0	0	1	0	0	0	1	0
85	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	1	0	0	0	1	0	0
87	0	0	0	0	1	0	0	0	1	0	0
88	0	0	0	0	1	0	0	0	1	0	0
89	0	0	0	0	1	0	0	0	1	0	0
90	0	0	0	0	1	0	0	0	1	0	0
91	0	0	1	0	1	0	0	0	1	0	1
92	0	0	1	0	1	0	0	0	1	0	1
93	0	0	1	0	1	0	0	0	1	0	1
94	0	0	1	0	1	0	0	0	1	0	1
95	0	0	1	0	1	0	0	0	1	0	1
96	0	0	0	0	0	1	0	0	0	1	0
97	0	0	0	0	0	1	0	0	0	1	0
98	0	0	0	0	0	1	0	0	0	1	0
99	0	0	0	0	0	1	0	0	0	1	0
100	0	0	0	0	0	1	0	0	0	1	0

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2	F3
101	57080-3505	469.15	6979.10	1277510	1
102	57080-3505	463.25	6979.10	1277510	1
103	57080-3505	493.05	6979.10	1277510	1
104	57080-3505	839.25	6979.10	1277510	1
105	57080-3505	881.00	6979.10	1277510	1
106	58050-3514	181.05	9304.80	2444275	1
107	58050-3514	1217.03	9304.80	2444275	1
108	58050-3514	1447.43	9304.80	2444275	1
109	58050-3514	1026.98	9304.80	2444275	1
110	58050-3514	935.32	9304.80	2444275	1
111	58050-3514	1002.55	9149.30	2444275	1
112	58050-3514	1521.08	9149.30	2444275	1
113	58050-3514	1127.51	9149.30	2444275	1
114	58050-3514	1019.00	9149.30	2444275	1
115	60060-3507	84.15	570.30	498722	0
116	60060-3507	168.95	570.30	498722	0
117	60060-3507	169.70	570.30	498722	0
118	60060-3507	147.00	570.30	498722	0
119	60580-3603	119.10	119.10	406333	1
120	61080-3524	1350.43	11775.30	1859693	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
101	0	0	0	0	1	0	0	0	1	0	1
102	0	0	0	0	1	0	0	0	1	0	1
103	0	0	0	0	1	0	0	0	1	0	1
104	0	0	0	0	1	0	0	0	1	0	1
105	0	0	0	0	1	0	0	0	1	0	1
106	0	0	0	0	1	0	0	0	1	0	0
107	0	0	0	0	1	0	0	0	1	0	0
108	0	0	0	0	1	0	0	0	1	0	0
109	0	0	0	0	1	0	0	0	1	0	0
110	0	0	0	0	1	0	0	0	1	0	0
111	0	0	0	0	1	0	0	0	1	0	0
112	0	0	0	0	1	0	0	0	1	0	0
113	0	0	0	0	1	0	0	0	1	0	0
114	0	0	0	0	1	0	0	0	1	0	0
115	1	0	0	0	1	0	0	0	0	1	0
116	1	0	0	0	1	0	0	0	0	1	0
117	1	0	0	0	1	0	0	0	0	1	0
118	1	0	0	0	1	0	0	0	0	1	0
119	0	0	0	0	1	0	0	1	0	0	0
120	0	0	0	0	1	0	0	0	1	0	0

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2	F3
121	61086-3522	354.55	.	330043	1
122	61086-3522	432.60	787.15	330043	1
123	70100-3547	278.40	4929.10	364027	1
124	70100-3547	346.20	4929.10	364027	1
125	70100-3547	359.90	4929.10	364027	1
126	70100-3547	306.00	4929.10	364027	1
127	70100-3547	359.90	4929.10	364027	1
128	72001-3456	1177.57	39846.40	1889673	1
129	72001-3456	1132.46	39846.40	1889673	1
130	72001-3456	1026.66	39846.40	1889673	1
131	72001-3456	1026.18	39846.40	1889673	1
132	72001-3456	1228.39	39846.40	1889673	1
133	72001-3456	1177.57	39864.40	1889673	1
134	72001-3456	1132.46	39864.40	1889673	1
135	72001-3456	1026.66	39864.40	1889673	1
136	72001-3456	1026.18	39864.40	1889673	1
137	72001-3456	1228.39	39864.40	1889673	1
138	72050-3542	689.37	5208.00	485923	1
139	72050-3542	423.44	5208.00	485923	1
140	72050-3542	568.20	5208.00	485923	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
121	0	0	0	0	0	1	0	0	1	0	0
122	0	0	0	0	0	1	0	0	1	0	0
123	0	0	0	0	0	1	0	0	0	1	0
124	0	0	0	0	0	1	0	0	0	1	0
125	0	0	0	0	0	1	0	0	0	1	0
126	0	0	0	0	0	1	0	0	0	1	0
127	0	0	0	0	0	1	0	0	0	1	0
128	0	0	0	0	0	0	1	0	0	1	0
129	0	0	0	0	0	0	1	0	0	1	0
130	0	0	0	0	0	0	1	0	0	1	0
131	0	0	0	0	0	0	1	0	0	1	0
132	0	0	0	0	0	0	1	0	0	1	0
133	0	0	0	0	0	0	1	0	0	1	0
134	0	0	0	0	0	0	1	0	0	1	0
135	0	0	0	0	0	0	1	0	0	1	0
136	0	0	0	0	0	0	1	0	0	1	0
137	0	0	0	0	0	0	1	0	0	1	0
138	0	0	0	0	0	1	0	0	0	1	0
139	0	0	0	0	0	1	0	0	0	1	0
140	0	0	0	0	0	1	0	0	0	1	0

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2	F3
141	72050-3542	736.88	5208.00	485923	1
142	72050-3542	478.12	5208.00	485923	1
143	72050-3542	689.37	5208.00	485923	1
144	72050-3542	423.44	5208.00	485923	1
145	72050-3542	586.20	5208.00	485923	1
146	72050-3542	736.88	5208.00	485923	1
147	72050-3542	478.12	5208.00	485923	1
148	72160-3551	1594.00	16652.00	4016077	1
149	72160-3551	535.00	16652.00	4016077	1
150	72160-3551	1275.00	16652.00	4016077	1
151	72160-3551	968.00	16652.00	4016077	1
152	72160-3551	811.00	16652.00	4016077	1
153	76000-3608	1053.04	11775.30	523676	1
154	76000-3608	1461.72	11775.30	523676	1
155	76000-3608	1118.19	11775.30	523676	1
156	76000-3608	1171.80	11775.30	523676	1
157	78010-3527	201.18	367.00	348638	0
158	78010-3527	20.82	367.00	348638	0
159	78010-3527	45.61	367.00	348638	0
160	78010-3527	41.17	367.00	348638	0

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
141	0	0	0	0	0	1	0	0	0	1	0
142	0	0	0	0	0	1	0	0	0	1	0
143	0	0	0	0	0	1	0	0	0	1	0
144	0	0	0	0	0	1	0	0	0	1	0
145	0	0	0	0	0	1	0	0	0	1	0
146	0	0	0	0	0	1	0	0	0	1	0
147	0	0	0	0	0	1	0	0	0	1	0
148	0	0	0	0	0	1	0	0	0	1	0
149	0	0	0	0	0	1	0	0	0	1	0
150	0	0	0	0	0	1	0	0	0	1	0
151	0	0	0	0	0	1	0	0	0	1	0
152	0	0	0	0	0	1	0	0	0	1	0
153	0	0	0	0	1	0	0	1	0	0	0
154	0	0	0	0	1	0	0	1	0	0	0
155	0	0	0	0	1	0	0	1	0	0	0
156	0	0	0	0	1	0	0	1	0	0	0
157	0	1	0	0	0	1	0	0	0	1	0
158	0	1	0	0	0	1	0	0	0	1	0
159	0	1	0	0	0	1	0	0	0	1	0
160	0	1	0	0	0	1	0	0	0	1	0

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2	F3
161	79170-3510	209.94	4912.10	563401	1
162	79170-3510	215.89	4912.10	563401	1
163	79170-3510	115.80	4912.10	563401	1
164	79170-3510	37.46	4912.10	563401	1
165	79170-3510	49.84	4912.10	563401	1
166	79190-3505	341.55	3106.80	796699	1
167	79190-3505	221.31	3106.80	796699	1
168	79190-3505	437.04	3106.80	796699	1
169	79190-3505	134.66	3106.80	796699	1
170	79190-3505	41.06	3106.80	796699	1
171	79210-3501	333.55	6424.00	392641	1
172	79210-3501	332.78	6424.00	392641	1
173	79210-3501	709.90	6424.00	392641	1
174	79210-3501	393.75	6424.00	392641	1
175	79210-3501	13.95	6424.00	392641	1
176	87055-3601	225.00	3600.98	1807970	1
177	87055-3601	247.50	3600.98	1807970	1
178	87055-3601	375.00	3600.98	1807970	1
179	87055-3601	232.50	3600.98	1807970	1
180	87055-3601	352.50	3600.98	1807970	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
161	0	0	0	0	0	1	0	0	0	1	0
162	0	0	0	0	0	1	0	0	0	1	0
163	0	0	0	0	0	1	0	0	0	1	0
164	0	0	0	0	0	1	0	0	0	1	0
165	0	0	0	0	0	1	0	0	0	1	0
166	0	0	0	0	0	1	0	0	0	1	0
167	0	0	0	0	0	1	0	0	0	1	0
168	0	0	0	0	0	1	0	0	0	1	0
169	0	0	0	0	0	1	0	0	0	1	0
170	0	0	0	0	0	1	0	0	0	1	0
171	0	0	0	0	1	0	0	0	1	0	1
172	0	0	0	0	1	0	0	0	1	0	1
173	0	0	0	0	1	0	0	0	1	0	1
174	0	0	0	0	1	0	0	0	1	0	1
175	0	0	0	0	1	0	0	0	1	0	1
176	0	0	0	0	0	1	0	0	0	1	0
177	0	0	0	0	0	1	0	0	0	1	0
178	0	0	0	0	0	1	0	0	0	1	1
179	0	0	0	0	0	1	0	0	0	1	0
180	0	0	0	0	0	1	0	0	0	1	0

DATA SET FOR ASPHALT PAVEMENT

OBS	PROJECT NUMBER	PRODUCTION RATE TN/DAY	F1	F2	F3
181	93060-3542	1123.00	24385.00	4039137	1
182	93060-3542	1431.00	24385.00	4039137	1
183	93060-3542	1325.00	24385.00	4039137	1
184	93060-3542	1638.00	24385.00	4039137	1
185	93060-3542	1163.00	24385.00	4039137	1
186	93230-3504	229.00	5588.00	413419	1
187	93230-3504	393.00	5588.00	413419	1
188	93230-3504	605.00	5588.00	413419	1

OBS	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	A1
181	0	0	0	0	0	1	0	0	1	0	0
182	0	0	0	0	0	1	0	0	1	0	0
183	0	0	0	0	0	1	0	0	1	0	0
184	0	0	0	0	0	1	0	0	1	0	0
185	0	0	0	0	0	1	0	0	1	0	0
186	0	0	0	0	1	0	0	0	1	0	0
187	0	0	0	0	1	0	0	0	1	0	0
188	0	0	0	0	1	0	0	0	1	0	0

DATA SET FOR STORM DRAIN

OBS	PROJECT NUMBER	PRODUCTION RATE LF/DAY	F1	F2
1	02010-3532	152.0	1281	177625.00
2	02010-3532	140.0	1281	177625.00
3	02010-3532	84.0	1281	177625.00
4	02010-3532	120.0	1281	177625.00
5	02010-3532	166.0	1281	177625.00
6	10160-3525	120.0	3000	4319100.35
7	10160-3525	128.0	3000	4319100.35
8	10160-3525	60.0	3000	4319100.35
9	10160-3525	64.0	3000	4319100.35
10	10160-3525	64.0	3000	4319100.35
11	11140-3507	48.0	472	345775.00
12	11140-3507	36.0	472	345775.00
13	11140-3507	34.0	472	345775.00
14	11140-3507	80.0	472	345775.00
15	12005-3507	5.0	80	339858.00
16	12005-3507	3.0	80	339858.00
17	12005-3507	6.0	80	339858.00
18	12005-3507	56.0	80	339858.00
19	12005-3507	8.0	80	339858.00
20	12020-3534	16.0	118	1369359.00

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	ST1	ST2
1	1	0	0	0	0	0	1	0	0	0	1	4.0	24
2	1	0	0	0	0	0	1	0	0	0	1	4.0	24
3	1	0	0	0	0	0	1	0	0	0	1	4.0	24
4	1	0	0	0	0	0	1	0	0	0	1	3.5	18
5	1	0	0	0	0	0	1	0	0	0	1	6.0	18
6	0	0	0	1	0	0	1	0	0	0	1	4.0	24
7	0	0	0	1	0	0	1	0	0	0	1	4.0	18
8	0	0	0	1	0	0	1	0	0	0	1	4.0	24
9	0	0	0	1	0	0	1	0	0	0	1	4.0	24
10	0	0	0	1	0	0	1	0	0	0	1	4.0	18
11	1	0	0	0	0	0	0	0	0	1	0	3.0	24
12	1	0	0	0	0	0	0	0	0	1	0	3.0	24
13	1	0	0	0	0	0	0	0	0	1	0	3.0	24
14	1	0	0	0	0	0	0	0	0	1	0	3.0	24
15	0	0	0	0	1	0	1	0	0	0	1	4.0	24
16	0	0	0	0	1	0	1	0	0	0	1	5.0	24
17	0	0	0	0	1	0	1	0	0	0	1	5.0	24
18	0	0	0	0	1	0	1	0	0	0	1	2.0	18
19	0	0	0	0	1	0	1	0	0	0	1	2.0	18
20	1	0	0	0	0	0	1	0	0	0	1	4.0	18

DATA SET FOR STORM DRAIN

OBS	PROJECT NUMBER	PRODUCTION RATE LF/DAY	F1	F2
21	12020-3534	8.0	118	1369359
22	12020-3534	16.0	118	1369359
23	12020-3534	7.0	118	1369359
24	12020-3534	71.0	118	1369359
25	35350-3502	64.0	.	2997476
26	35350-3502	52.0	.	2997476
27	35350-3502	60.0	.	2997476
28	35350-3502	96.0	.	2997476
29	35350-3502	174.0	.	2997476
30	36090-3506	8.5	12	1816321
31	36090-3506	4.0	12	1816321
32	36570-3605	8.0	76	143684
33	36570-3605	20.0	76	143684
34	36570-3605	8.0	76	143684
35	36570-3605	40.0	76	143684
36	46040-3545	108.0	176	182576
37	46040-3545	44.0	176	182576
38	48060-3506	76.0	314	4026596
39	48060-3506	64.0	314	4026596
40	48060-3506	88.0	314	4026596

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	ST1	ST2
21	1	0	0	0	0	0	1	0	0	0	1	10.0	72
22	1	0	0	0	0	0	1	0	0	0	1	10.0	72
23	1	0	0	0	0	0	1	0	0	0	1	10.0	72
24	1	0	0	0	0	0	1	0	0	0	1	2.5	12
25	0	0	0	1	0	1	0	0	0	0	1	7.0	15
26	0	0	0	1	0	1	0	0	0	0	1	7.0	15
27	0	0	0	1	0	1	0	0	0	0	1	7.0	18
28	0	0	0	1	0	1	0	0	0	0	1	7.0	24
29	0	0	0	1	0	1	0	0	0	0	1	7.0	36
30	1	0	0	0	0	1	0	0	1	0	0	3.0	24
31	1	0	0	0	0	1	0	0	1	0	0	3.0	24
32	0	0	1	0	0	1	0	0	1	0	0	4.0	18
33	0	0	1	0	0	1	0	0	1	0	0	4.0	18
34	0	0	1	0	0	1	0	0	1	0	0	3.0	30
35	0	0	1	0	0	1	0	0	1	0	0	3.0	18
36	0	0	0	0	0	0	0	0	0	0	1	8.0	24
37	0	0	0	0	0	0	0	0	0	0	1	8.0	24
38	1	0	0	0	0	1	0	0	0	0	1	4.0	18
39	1	0	0	0	0	1	0	0	0	0	1	4.0	18
40	1	0	0	0	0	1	0	0	0	0	1	4.0	18

DATA SET FOR STORM DRAIN

OBS	PROJECT NUMBER	PRODUCTION RATE LF/DAY	F1	F2
41	48060-3506	16	314	4026596
42	5060-3510	72	557	1713257
43	5060-3510	32	.	1713257
44	5060-3510	64	.	1713257
45	5060-3510	73	.	1713257
46	5060-3510	64	.	1713257
47	53030-3510	92	5059	7205002
48	53030-3510	88	5059	7205002
49	53030-3510	102	5059	7205002
50	53030-3510	72	5059	7205002
51	53030-3510	76	5059	7205002
52	55040-3525	25	95	1194647
53	57030-3548	144	3034	7678699
54	57030-3548	100	.	7678699
55	57030-3548	16	.	7678699
56	57030-3548	32	.	7678699
57	57030-3548	56	.	7678699
58	57040-3558	6	765	3954939
59	57040-3558	8	765	3954939
60	57040-3558	32	765	3954939

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	ST1	ST2
41	1	0	0	0	0	1	0	0	0	0	1	4.0	18
42	1	0	0	0	0	1	0	0	1	0	0	3.5	18
43	1	0	0	0	0	1	0	0	1	0	0	3.5	18
44	1	0	0	0	0	1	0	0	1	0	0	3.5	18
45	1	0	0	0	0	1	0	0	1	0	0	3.5	18
46	1	0	0	0	0	1	0	0	1	0	0	3.5	18
47	0	0	0	1	0	1	0	0	0	1	0	5.0	18
48	0	0	0	1	0	1	0	0	0	1	0	4.0	15
49	0	0	0	1	0	1	0	0	0	1	0	4.0	15
50	0	0	0	1	0	1	0	0	0	1	0	5.0	18
51	0	0	0	1	0	1	0	0	0	1	0	5.0	18
52	1	0	0	0	0	0	0	0	0	0	0	4.0	30
53	0	0	0	1	0	1	0	0	0	1	0	7.0	42
54	0	0	0	1	0	1	0	0	0	1	0	7.0	42
55	0	0	0	1	0	1	0	0	0	1	0	6.0	36
56	0	0	0	1	0	1	0	0	0	1	0	4.0	15
57	0	0	0	1	0	1	0	0	0	1	0	8.0	60
58	1	0	0	0	0	0	1	0	0	0	1	4.0	24
59	1	0	0	0	0	0	1	0	0	0	1	7.0	60
60	1	0	0	0	0	0	1	0	0	0	1	7.0	60

DATA SET FOR STORM DRAIN

OBS	PROJECT NUMBER	PRODUCTION RATE LF/DAY	F1	F2
61	57040-3558	8	765	3954939
62	57040-3558	168	765	3954939
63	57040-3561	36	125	3734203
64	57040-3561	40	125	3734203
65	57040-3561	12	125	3734203
66	57040-3561	12	125	3734203
67	57040-3561	12	125	3734203
68	58050-3514	24	.	2444275
69	58050-3514	8	.	2444275
70	61086-3522	24	307	330043
71	61086-3522	64	307	330043
72	61086-3522	81	307	330043
73	61086-3522	46	307	330043
74	72160-3551	116	14377	4016077
75	72160-3551	120	14377	4016077
76	72160-3551	72	14377	4016077
77	72160-3551	128	14377	4016077
78	72160-3551	80	14377	4016077
79	79170-3510	24	266	563401
80	79170-3510	136	266	563401

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	ST1	ST2
61	1	0	0	0	0	0	1	0	0	0	1	7.0	60
62	1	0	0	0	0	0	1	0	0	0	1	4.0	15
63	0	0	0	0	0	0	1	0	0	0	1	9.0	36
64	0	0	0	0	0	0	1	0	0	0	1	9.0	36
65	0	0	0	0	0	0	1	0	0	0	1	9.0	48
66	0	0	0	0	0	0	1	0	0	0	1	9.0	42
67	0	0	0	0	0	0	1	0	0	0	1	9.0	42
68	1	0	0	0	0	1	0	0	0	1	0	4.0	30
69	1	0	0	0	0	1	0	0	0	1	0	4.0	30
70	1	0	0	0	0	0	1	0	0	1	0	5.0	24
71	1	0	0	0	0	0	1	0	0	1	0	5.0	24
72	1	0	0	0	0	0	1	0	0	1	0	5.0	24
73	1	0	0	0	0	0	1	0	0	1	0	5.0	24
74	1	0	0	0	0	0	1	0	0	0	1	4.0	15
75	1	0	0	0	0	0	1	0	0	0	1	4.0	18
76	1	0	0	0	0	0	1	0	0	0	1	6.0	36
77	1	0	0	0	0	0	1	0	0	0	1	7.0	36
78	1	0	0	0	0	0	1	0	0	0	1	7.0	36
79	1	0	0	0	0	0	1	0	0	0	1	4.0	18
80	1	0	0	0	0	0	1	0	0	0	1	4.0	30

DATA SET FOR STORM DRAIN

OBS	PROJECT NUMBER	PRODUCTION RATE LF/DAY	F1	F2
81	79170-3510	80	266	563401
82	79170-3510	16	266	563401
83	79190-3505	24	232	796699
84	79190-3505	24	232	796699
85	79190-3505	48	232	796699
86	79190-3505	36	232	796699
87	79190-3505	9	232	796699
88	87055-3601	48	7413	1807970
89	87055-3601	150	7413	1807970
90	87055-3601	24	7413	1807970
91	87055-3601	80	7413	1807970
92	87055-3601	72	7413	1807970
93	93060-3542	100	800	4039137
94	93060-3542	88	800	4039137
95	93060-3542	58	800	4039137
96	93060-3542	150	800	4039137
97	93060-3542	100	800	4039137

OBS	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	ST1	ST2
81	1	0	0	0	0	0	1	0	0	0	1	4.0	30
82	1	0	0	0	0	0	1	0	0	0	1	4.0	30
83	1	0	0	0	0	0	1	0	0	0	1	4.0	18
84	1	0	0	0	0	0	1	0	0	0	1	3.0	18
85	1	0	0	0	0	0	1	0	0	0	1	4.0	18
86	1	0	0	0	0	0	1	0	0	0	1	4.0	18
87	1	0	0	0	0	0	1	0	0	0	1	3.0	18
88	1	0	0	0	0	0	1	0	0	0	1	6.5	30
89	1	0	0	0	0	0	1	0	0	0	1	6.5	30
90	1	0	0	0	0	0	1	0	0	0	1	6.5	30
91	1	0	0	0	0	0	1	0	0	0	1	6.5	18
92	1	0	0	0	0	0	1	0	0	0	1	6.5	18
93	1	0	0	0	0	0	1	0	0	1	0	7.0	18
94	1	0	0	0	0	0	1	0	0	1	0	7.0	18
95	1	0	0	0	0	0	1	0	0	1	0	7.0	18
96	1	0	0	0	0	0	1	0	0	1	0	7.0	36
97	1	0	0	0	0	0	1	0	0	1	0	7.0	18

APPENDIX C

REGRESSION COMPUTER OUTPUT

MODEL SELECTION CLEAR AND GRUBBNG

Maximum R-square Improvement for Dependent Variable PROD_RT

Step 1 Variable PRICE Entered R-square = 0.15062492
C(p) = 40.06365686

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	1	92.42906827	92.42906827	15.43	0.0002
Error	87	521.20824479	5.99089937		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	1.36975453	0.38663997	75.19068029	12.55	0.0006
PRICE	0.00000032	0.00000008	92.42906827	15.43	0.0002

Bounds on condition number: 1, 1

The above model is the best 1-variable model found.

Step 2 Variable TOT_QTY2 Entered R-square = 0.21251067
C(p) = 32.95147626

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	2	130.40447836	65.20223918	11.60	0.0001
Error	86	483.23283470	5.61898645		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	1.03277691	0.39624743	38.17140222	6.79	0.0108
PRICE	0.00000058	0.00000013	116.04700470	20.65	0.0001
TOT_QTY2	-0.00008317	0.00003199	37.97541009	6.76	0.0110

MODEL SELECTION CLEAR AND GRUBBNG

Bounds on condition number: 2.64274, 10.57096

The above model is the best 2-variable model found.

Step 3 Variable TOT_QTY Entered R-square = 0.43631166
C(p) = 1.99857940

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	3	267.73711333	89.24570444	21.93	0.0001
Error	85	345.90019972	4.06941411		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.08076872	0.37492402	0.18885644	0.05	0.8300
TOT_QTY	0.07537392	0.01297479	137.33263497	33.75	0.0001
PRICE	0.00000030	0.00000012	26.30216390	6.46	0.0128
TOT_QTY2	-0.00039076	0.00005954	175.29338216	43.08	0.0001

Bounds on condition number: 15.08104, 92.62268

The above model is the best 3-variable model found.

Step 4 Variable RURAL Entered R-square = 0.45342082
C(p) = 1.47939235

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	4	278.23593522	69.55898381	17.42	0.0001
Error	84	335.40137783	3.99287355		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F

MODEL SELECTION CLEAR AND GRUBBNG

INTERCEP	0.38702458	0.41664732	3.44528752	0.86	0.3556
TOT_QTY	0.08437640	0.01400005	145.03360090	36.32	0.0001
PRICE	0.00000018	0.00000014	6.34741727	1.59	0.2109
RURAL	-0.95298576	0.58770435	10.49882189	2.63	0.1086
TOT_QTY2	-0.00039573	0.00005906	179.29930271	44.90	0.0001

Bounds on condition number: 17.89518, 147.1689

The above model is the best 4-variable model found.

Step 5 Variable TYP_H Entered R-square = 0.46493459
C(p) = 1.78408213

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	5	285.30121452	57.06024290	14.42	0.0001
Error	83	328.33609854	3.95585661		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.10602908	0.46496727	0.20570544	0.05	0.8202
TOT_QTY	0.09386976	0.01564112	142.48076542	36.02	0.0001
PRICE	0.00000014	0.00000014	4.16820816	1.05	0.3076
RURAL	-1.32744576	0.64861683	16.56905278	4.19	0.0439
TOT_QTY2	-0.00043583	0.00006599	172.52921151	43.61	0.0001
TYP_H	0.70348510	0.52639349	7.06527929	1.79	0.1851

Bounds on condition number: 22.5454, 233.8393

The above model is the best 5-variable model found.

MODEL SELECTION CLEAR AND GRUBBNG

Step 6 Variable MEDIUM Entered R-square = 0.48172237
C(p) = 1.31221681

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	6	295.60282106	49.26713684	12.70	0.0001
Error	82	318.03449199	3.87846941		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.26758423	0.47094763	1.25209181	0.32	0.5715
TOT_QTY	0.09742953	0.01564064	150.49862334	38.80	0.0001
PRICE	0.00000015	0.00000014	4.44294207	1.15	0.2876
RURAL	-1.38114286	0.64308574	17.88956667	4.61	0.0347
MEDIUM	-0.80134930	0.49169927	10.30160654	2.66	0.1070
TOT_QTY2	-0.00044383	0.00006553	177.91859377	45.87	0.0001
TYP_H	1.03567613	0.55965674	13.28204138	3.42	0.0678

Bounds on condition number: 22.99384, 293.5325

The above model is the best 6-variable model found.

Step 7 Variable TYP_M Entered R-square = 0.48521947
C(p) = 2.79729688

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	7	297.74877231	42.53553890	10.91	0.0001
Error	81	315.88854074	3.89985853		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares

MODEL SELECTION CLEAR AND GRUBBNG

F Prob>F

INTERCEP	-0.36818386	0.97855681	0.55208539	0.14	0.7077
TOT_QTY	0.10237788	0.01704341	140.71756535	36.08	0.0001
PRICE	0.00000019	0.00000015	6.29111261	1.61	0.2077
RURAL	-1.39804647	0.64525905	18.30728148	4.69	0.0332
MEDIUM	-0.82961686	0.49452363	10.97564111	2.81	0.0973
TOT_QTY2	-0.00047133	0.00007544	152.20737515	39.03	0.0001
TYP_M	0.59187014	0.79788616	2.14595125	0.55	0.4604
TYP_H	1.51850631	0.85942035	12.17505092	3.12	0.0810

Bounds on condition number: 27.15356, 453.581

The above model is the best 7-variable model found.

Step 8 Variable RC Entered R-square = 0.48831956
C(p) = 4.34083423

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	8	299.65110032	37.45638754	9.54	0.0001
Error	80	313.98621273	3.92482766		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-0.61099370	1.04179745	1.34998042	0.34	0.5592
TOT_QTY	0.10501718	0.01751312	141.12834200	35.96	0.0001
PRICE	0.00000018	0.00000015	5.79117159	1.48	0.2280
RC	0.31437043	0.45155358	1.90232801	0.48	0.4883
RURAL	-1.51498812	0.66875974	20.14182422		

MODEL SELECTION CLEAR AND GRUBBNG

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
				5.13	0.0262
MEDIUM	-0.80759177	0.49711190	10.35848001	2.64	0.1082
TOT_QTY2	-0.00047906	0.00007650	153.92865355	39.22	0.0001
TYP_M	0.63804867	0.80317991	2.47686617	0.63	0.4293
TYP_H	1.62790510	0.87637009	13.54265045	3.45	0.0669

Bounds on condition number: 28.48848, 544.5593

The above model is the best 8-variable model found.

Step 9 Variable II Entered R-square = 0.49317558
C(p) = 5.62582444

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	9	302.63093479	33.62565942	8.54	0.0001
Error	79	311.00637826	3.93678960		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-1.10225839	1.18637934	3.39830127	0.86	0.3557
TOT_QTY	0.11122891	0.01893730	135.81306828	34.50	0.0001
PRICE	0.00000023	0.00000016	7.92988721	2.01	0.1598
RC	0.47682142	0.48927240	3.73897258	0.95	0.3328
II	0.97774329	1.12382808	2.97983447	0.76	0.3869
RURAL	-1.49230691	0.67028525	19.51367978	4.96	0.0288
MEDIUM	-1.00587714	0.54755541	13.28543940	3.37	0.0700
TOT_QTY2	-0.00051139	0.00008515	141.99375802	36.07	0.0001
TYP_M	0.77859711	0.82046436	3.54526205	0.90	0.3455

MODEL SELECTION CLEAR AND GRUBBNG

TYP_H	1.96018373	0.95719985	16.50937070	4.19	0.0439

Bounds on condition number: 33.20906, 734.8667

The above model is the best 9-variable model found.

Step10 Variable LIMITED Entered R-square = 0.49582888
C(p) = 7.23514629

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	10	304.25910304	30.42591030	7.67	0.0001
Error	78	309.37821001	3.96638731		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-1.34382956	1.24909593	4.59083739	1.16	0.2853
TOT_QTY	0.11247935	0.01910828	137.43499259	34.65	0.0001
PRICE	0.00000021	0.00000016	6.52456837	1.64	0.2034
RC	0.44068799	0.49433581	3.15219740	0.79	0.3754
II	1.07254928	1.13770872	3.52506764	0.89	0.3487
RURAL	-1.38236581	0.69433812	15.72168423	3.96	0.0500
LIMITED	0.79387092	1.23907561	1.62816825	0.41	0.5236
MEDIUM	-1.20626501	0.63237134	14.43232233	3.64	0.0601
TOT_QTY2	-0.00051699	0.00008592	143.61876993	36.21	0.0001
TYP_M	1.08023486	0.94861609	5.14340263	1.30	0.2583
TYP_H	2.35424159	1.14079014	16.89217850	4.26	0.0424

Bounds on condition number: 33.55915, 895.6969

MODEL SELECTION CLEAR AND GRUBBNG

The above model is the best 10-variable model found.

Step11 Variable NC Entered R-square = 0.49658671
C(p) = 9.12356181

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	11	304.72413622	27.70219420	6.91	0.0001
Error	77	308.91317683	4.01185944		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-1.35204737	1.25646744	4.64544206	1.16	0.2853
TOT_QTY	0.10749993	0.02414988	79.49360726	19.81	0.0001
PRICE	0.00000021	0.00000016	6.35370916	1.58	0.2120
RC	0.58397583	0.65137903	3.22454100	0.80	0.3728
II	1.09666737	1.14640246	3.67131235	0.92	0.3418
NC	0.36250468	1.06474228	0.46503318	0.12	0.7344
RURAL	-1.35760176	0.70208480	15.00069418	3.74	0.0568
LIMITED	1.02248392	1.41555377	2.09317693	0.52	0.4723
MEDIUM	-1.15247536	0.65531586	12.40816769	3.09	0.0826
TOT_QTY2	-0.00049982	0.00010005	100.11932536	24.96	0.0001
TYP_M	1.03431793	0.96352370	4.62305450	1.15	0.2864
TYP_H	2.24429855	1.19188967	14.22442925	3.55	0.0635

Bounds on condition number: 52.99647, 1386.106

The above model is the best 11-variable model found.

MODEL SELECTION CLEAR AND GRUBBNG

Step12 Variable NB Entered R-square = 0.49739051
C(p) = 11.00520957

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	12	305.21737435	25.43478120	6.27	0.0001
Error	76	308.41993871	4.05815709		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-1.47971862	1.31568925	5.13310888	1.26	0.2643
TOT_QTY	0.10587379	0.02473264	74.36434713	18.32	0.0001
PRICE	0.00000020	0.00000017	5.48859078	1.35	0.2485
RC	0.75709081	0.82204733	3.44216077	0.85	0.3600
NB	0.45762921	1.31265274	0.49323812	0.12	0.7283
II	1.24812000	1.23212362	4.16421336	1.03	0.3143
NC	0.62294483	1.30569071	0.92373500	0.23	0.6347
RURAL	-1.29502557	0.72858005	12.82126825	3.16	0.0795
LIMITED	1.27129778	1.59256792	2.58599397	0.64	0.4272
MEDIUM	-1.18419005	0.66533462	12.85557248	3.17	0.0791
TOT_QTY2	-0.00049218	0.00010299	92.68607800	22.84	0.0001
TYP_M	1.05694254	0.97123790	4.80596237	1.18	0.2799
TYP_H	2.16941759	1.21783758	12.87764435	3.17	0.0788

Bounds on condition number: 54.95091, 1654.153

The above model is the best 12-variable model found.

MODEL SELECTION CLEAR AND GRUBBNG

Step13 Variable HEAVY Entered R-square = 0.49740696
C(p) = 13.00278630

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	13	305.22747341	23.47903642	5.71	0.0001
Error	75	308.40983965	4.11213120		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-1.56176250	2.12011034	2.23141329	0.54	0.4636
TOT_QTY	0.10534514	0.02708565	62.20389374	15.13	0.0002
PRICE	0.00000019	0.00000017	5.46340208	1.33	0.2527
RC	0.76935595	0.86371470	3.26272878	0.79	0.3759
NB	0.46724565	1.33552552	0.50333034	0.12	0.7274
II	1.26508184	1.28664961	3.97542553	0.97	0.3287
NC	0.64066488	1.36211495	0.90970645	0.22	0.6395
RURAL	-1.26460744	0.95636652	7.19001341	1.75	0.1901
LIMITED	1.32878210	1.97876446	1.85432690	0.45	0.5040
MEDIUM	-1.12675576	1.33855146	2.91377755	0.71	0.4026
HEAVY	0.08239762	1.66267604	0.01009906	0.00	0.9606
TOT_QTY2	-0.00049047	0.00010926	82.86370231	20.15	0.0001
TYP_M	1.05844360	0.97814446	4.81500129	1.17	0.2827
TYP_H	2.18553138	1.26829812	12.21063799	2.97	0.0890

Bounds on condition number: 65.03905, 2338.732

The above model is the best 13-variable model found.

MODEL SELECTION CLEAR AND GRUBBNG

Step14 Variable URBAN Entered R-square = 0.49742589
C(p) = 15.00000000

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	14	305.23908545	21.80279182	5.23	0.0001
Error	74	308.39822760	4.16754362		
Total	88	613.63731306			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-1.57292851	2.14480423	2.24141776	0.54	0.4657
TOT_QTY	0.10560883	0.02772135	60.48557493	14.51	0.0003
PRICE	0.00000020	0.00000018	5.05934014	1.21	0.2741
RC	0.76934750	0.86951467	3.26265700	0.78	0.3791
NB	0.47189054	1.34737028	0.51119755	0.12	0.7272
II	1.28723085	1.36155905	3.72494675	0.89	0.3475
NC	0.62610578	1.39872566	0.83504618	0.20	0.6557
RURAL	-1.29511776	1.12296615	5.54326110	1.33	0.2525
URBAN	-0.05289078	1.00199544	0.01161204	0.00	0.9580
LIMITED	1.30948176	2.02533022	1.74215733	0.42	0.5199
MEDIUM	-1.13005921	1.34899245	2.92458003	0.70	0.4049
HEAVY	0.09131215	1.68233925	0.01227750	0.00	0.9569
TOT_QTY2	-0.00049196	0.00011354	78.24770388	18.78	0.0001
TYP_M	1.10120523	1.27511778	3.10825100	0.75	0.3906
TYP_H	2.22541984	1.48367643	9.37617423	2.25	0.1379

Bounds on condition number: 67.222, 2796.588

MODEL SELECTION CLEAR AND GRUBBNG

The above model is the best 14-variable model found.

No further improvement in R-square is possible.

PREDICTION MODEL FOR CLEAR AND GRUBB

Model: MODEL1
Dependent Variable: PROD_RT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	13	305.22747	23.47904	5.710	0.0001
Error	75	308.40984	4.11213		
C Total	88	613.63731			

Root MSE	2.02784	R-square	0.4974
Dep Mean	2.49574	Adj R-sq	0.4103
C.V.	81.25196		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0
INTERCEP	1	-1.561763	2.12011034	-0.737
TOT_QTY	1	0.105345	0.02708565	3.889
PRICE	1	0.000000195	0.00000017	1.153
RC	1	0.769356	0.86371470	0.891
NB	1	0.467246	1.33552552	0.350
II	1	1.265082	1.28664961	0.983
NC	1	0.640665	1.36211495	0.470
RURAL	1	-1.264607	0.95636652	-1.322
LIMITED	1	1.328782	1.97876446	0.672
MEDIUM	1	-1.126756	1.33855146	-0.842
HEAVY	1	0.082398	1.66267604	0.050
TOT_QTY2	1	-0.000490	0.00010926	-4.489
TYP_M	1	1.058444	0.97814446	1.082
TYP_H	1	2.185531	1.26829812	1.723

Variable	DF	Prob > |T|
INTERCEP	1	0.4636
TOT_QTY	1	0.0002
PRICE	1	0.2527
RC	1	0.3759
NB	1	0.7274
II	1	0.3287

PREDICTION MODEL FOR CLEAR AND GRUBB

Variable	DF	Prob > |T|
NC	1	0.6395
RURAL	1	0.1901
LIMITED	1	0.5040
MEDIUM	1	0.4026
HEAVY	1	0.9606
TOT_QTY2	1	0.0001
TYP_M	1	0.2827
TYP_H	1	0.0890

PREDICTION MODEL FOR CLEAR AND GRUBB

Obs	Dep Var PROD_RT	Predict Value	Residual
1	1.0000	1.3860	-0.3860
2	1.0000	1.3860	-0.3860
3	1.0000	1.3860	-0.3860
4	1.0000	1.3860	-0.3860
5	1.0000	1.3860	-0.3860
6	0.4000	1.5522	-1.1522
7	4.5000	5.2831	-0.7831
8	5.6500	5.2831	0.3669
9	5.6500	5.2831	0.3669
10	5.1000	5.2831	-0.1831
11	0.8400	3.0532	-2.2132
12	7.9800	3.0532	4.9268
13	5.8800	3.0532	2.8268
14	1.2600	3.0532	-1.7932
15	0.4200	3.0532	-2.6332
16	3.8000	6.0135	-2.2135
17	7.2500	6.0135	1.2365
18	11.1900	6.0135	5.1765
19	10.3300	6.0135	4.3165
20	10.3300	6.0135	4.3165
21	3.0000	1.2083	1.7917
22	3.0000	1.2083	1.7917
23	2.6500	1.2083	1.4417
24	0.1000	.	.
25	0.1200	.	.
26	1.1000	2.5281	-1.4281
27	1.4000	2.5281	-1.1281
28	1.3000	2.5281	-1.2281
29	1.7000	2.5281	-0.8281
30	1.6000	2.5281	-0.9281
31	0.4900	.	.
32	0.1300	.	.
33	0.2300	.	.
34	0.2700	.	.
35	0.6500	.	.
36	4.8450	2.9148	1.9302
37	1.0400	-0.2763	1.3163
38	8.2300	4.1570	4.0730

PREDICTION MODEL FOR CLEAR AND GRUBB

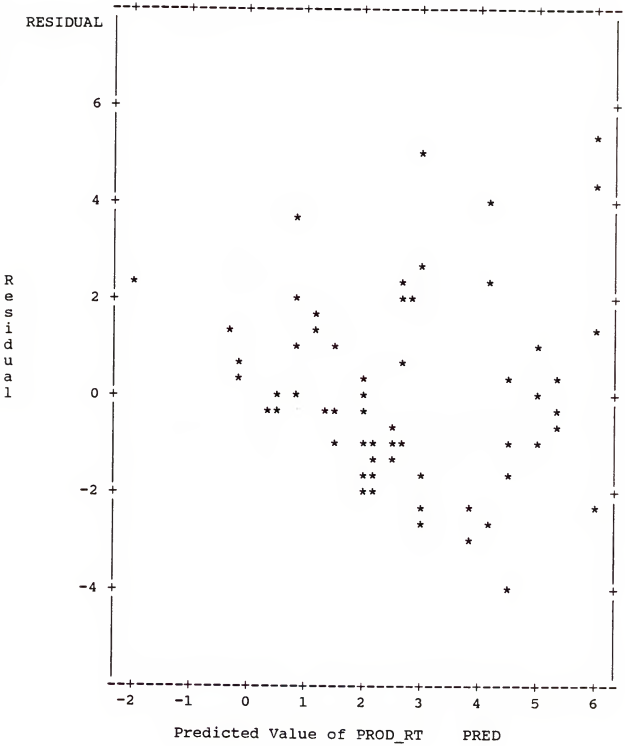
Obs	Dep Var PROD_RT	Predict Value	Residual
39	8.2300	4.1570	4.0730
40	1.6400	4.1570	-2.5170
41	6.5800	4.1570	2.4230
42	0.1300	-0.2350	0.3650
43	0.1700	-0.2350	0.4050
44	0.1300	-0.2350	0.3650
45	0.1300	-0.2350	0.3650
46	0.2900	-0.2350	0.5250
47	1.7000	3.8866	-2.1866
48	1.0000	3.8866	-2.8866
49	1.7000	3.8866	-2.1866
50	1.0000	3.8866	-2.8866
51	0.7500	3.8866	-3.1366
52	2.7000	0.8623	1.8377
53	4.5000	0.8623	3.6377
54	0.9000	0.8623	0.0377
55	1.8000	0.8623	0.9377
56	1.8000	0.8623	0.9377
57	0.0400	0.3518	-0.3118
58	0.0200	0.3518	-0.3318
59	0.0700	0.3518	-0.2818
60	0.0500	0.3518	-0.3018
61	0.0300	0.3518	-0.3218
62	0.1900	0.4340	-0.2440
63	0.2800	0.4340	-0.1540
64	0.5600	0.4340	0.1260
65	0.5700	0.4340	0.1360
66	0.5700	0.4340	0.1360
67	5.0000	4.9535	0.0465
68	4.0000	4.9535	-0.9535
69	6.0000	4.9535	1.0465
70	5.0000	4.9535	0.0465
71	5.0000	4.9535	0.0465
72	2.6400	4.4524	-1.8124
73	2.7000	4.4524	-1.7524
74	0.5000	4.4524	-3.9524
75	4.8200	4.4524	0.3676
76	3.5500	4.4524	-0.9024

PREDICTION MODEL FOR CLEAR AND GRUBB

Obs	Dep Var PROD_RT	Predict Value	Residual
77	0.0180	2.0430	-2.0250
78	2.4000	1.4373	0.9627
79	0.4000	1.4373	-1.0373
80	1.0000	1.4373	-0.4373
81	1.8600	1.9712	-0.1112
82	2.3270	1.9712	0.3558
83	1.5710	1.9712	-0.4002
84	0.1780	1.9712	-1.7932
85	0.8320	1.9712	-1.1392
86	0.4000	2.1706	-1.7706
87	0.4000	2.1706	-1.7706
88	1.3000	2.1706	-0.8706
89	0.3000	2.1706	-1.8706
90	0.7000	2.1706	-1.4706
91	3.2000	2.6135	0.5865
92	4.5000	2.6135	1.8865
93	1.6000	2.6135	-1.0135
94	1.6000	2.6135	-1.0135
95	5.1000	2.6135	2.4865
96	0.2500	-2.0184	2.2684

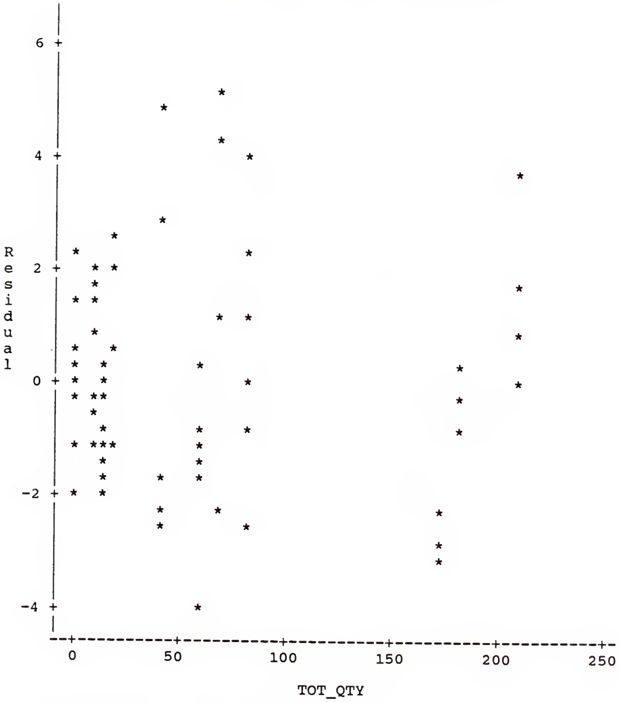
Sum of Residuals	3.23741E-13
Sum of Squared Residuals	308.4098
Predicted Resid SS (Press)	446.2084

PREDICTION MODEL FOR CLEAR AND GRUBB



PREDICTION MODEL FOR CLEAR AND GRUBB

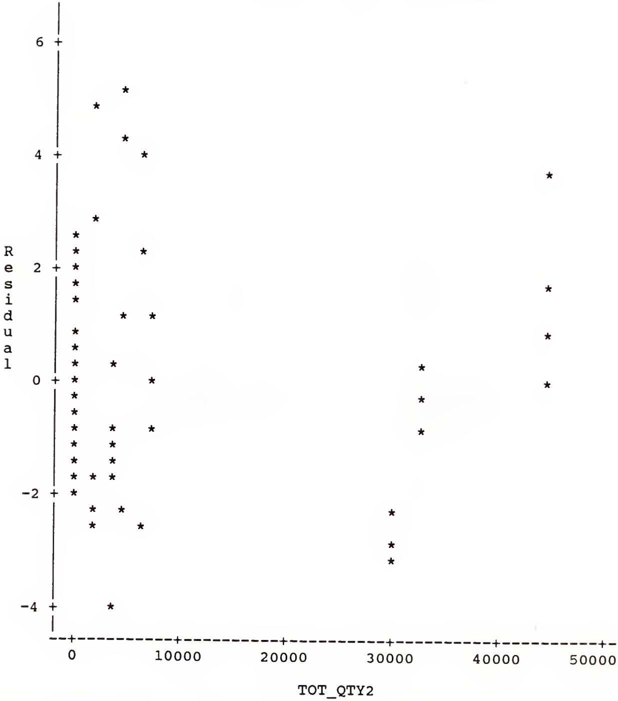
Plot of YRESID*TOT_QTY. Symbol used is '*'.



NOTE: 7 obs had missing values. 31 obs hidden.

PREDICTION MODEL FOR CLEAR AND GRUBB

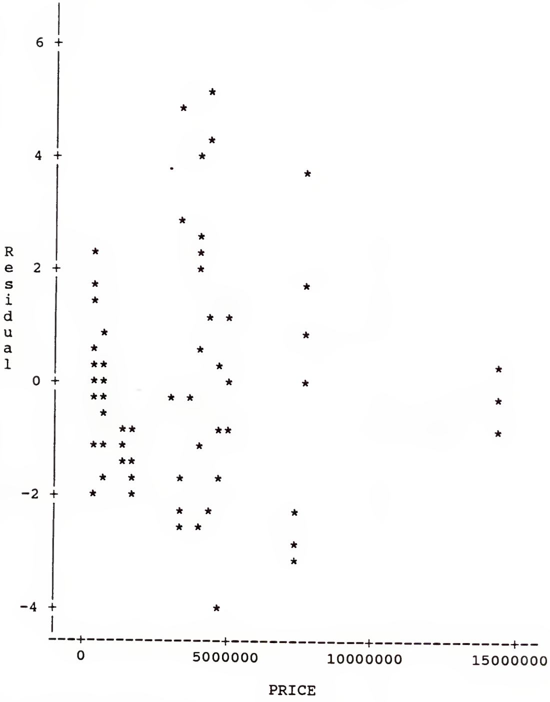
Plot of YRESID*TOT_QTY2. Symbol used is '*'.



NOTE: 7 obs had missing values. 42 obs hidden.

PREDICTION MODEL FOR CLEAR AND GRUBB

Plot of YRESID*PRICE. Symbol used is '*'.



NOTE: 7 obs had missing values. 31 obs hidden.

PREDICTION MODEL FOR CLEARING AND GRUBBING

Model: MODEL1
Dependent Variable: LOG_PR

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	12	133.83873	11.15323	14.180	0.0001
Error	76	59.77836	0.78656		
C Total	88	193.61709			

Root MSE	0.88688	R-square	0.6913
Dep Mean	0.17149	Adj R-sq	0.6425
C.V.	517.15764		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.

SG = 0
HEAVY = +1.0000 * INTERCEP -1.0000 * LIGHT -1.0000 * MEDIUM

PREDICTION MODEL FOR CLEARING AND GRUBBING

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0
INTERCEP	B	-1.181892	0.48379543	-2.443
LOG_TQ	1	0.567505	0.11593198	4.895
RC	1	0.692154	0.43686895	1.584
NB	1	0.705082	0.62029991	1.137
II	1	0.122397	0.57842904	0.212
NC	1	0.330528	0.62131457	0.532
SG	0	0	0.00000000	.
LIGHT	B	0.283303	0.66418594	0.427
MEDIUM	B	0.054329	0.38889080	0.140
HEAVY	0	0	0.00000000	.
TYP_M	1	-0.244324	0.47547398	-0.514
TYP_H	1	-0.021495	0.55347019	-0.039
RURAL	1	-1.139281	0.39578642	-2.879
URBAN	1	-0.578627	0.40836230	-1.417
LIMITED	1	-0.259863	0.70858268	-0.367

Variable	DF	Prob > |T|
INTERCEP	B	0.0169
LOG_TQ	1	0.0001
RC	1	0.1173
NB	1	0.2592
II	1	0.8330
NC	1	0.5963
SG	0	.
LIGHT	B	0.6709
MEDIUM	B	0.8893
HEAVY	0	.
TYP_M	1	0.6088
TYP_H	1	0.9691
RURAL	1	0.0052
URBAN	1	0.1606
LIMITED	1	0.7148

PREDICTION MODEL FOR CLEARING AND GRUBBING

Obs	Dep Var LOG_PR	Predict Value	Std Err Predict	Lower95% Mean	Upper95% Mean
1	0	0.1575	0.378	-0.5944	0.9094
2	0	0.1575	0.378	-0.5944	0.9094
3	0	0.1575	0.378	-0.5944	0.9094
4	0	0.1575	0.378	-0.5944	0.9094
5	0	0.1575	0.378	-0.5944	0.9094
6	-0.9163	-1.6099	0.458	-2.5230	-0.6968
7	1.5041	2.2518	0.366	1.5231	2.9804
8	1.7317	2.2518	0.366	1.5231	2.9804
9	1.7317	2.2518	0.366	1.5231	2.9804
10	1.6292	2.2518	0.366	1.5231	2.9804
11	-0.1744	0.1633	0.245	-0.3242	0.6509
12	2.0769	0.1633	0.245	-0.3242	0.6509
13	1.7716	0.1633	0.245	-0.3242	0.6509
14	0.2311	0.1633	0.245	-0.3242	0.6509
15	-0.8675	0.1633	0.245	-0.3242	0.6509
16	1.3350	0.7326	0.295	0.1441	1.3210
17	1.9810	0.7326	0.295	0.1441	1.3210
18	2.4150	0.7326	0.295	0.1441	1.3210
19	2.3351	0.7326	0.295	0.1441	1.3210
20	2.3351	0.7326	0.295	0.1441	1.3210
21	1.0986	0.7675	0.395	-0.0195	1.5545
22	1.0986	0.7675	0.395	-0.0195	1.5545
23	0.9746	0.7675	0.395	-0.0195	1.5545
24	-2.3026	.	.	.	.
25	-2.1203	.	.	.	.
26	0.0953	0.4751	0.310	-0.1414	1.0917
27	0.3365	0.4751	0.310	-0.1414	1.0917
28	0.2624	0.4751	0.310	-0.1414	1.0917
29	0.5306	0.4751	0.310	-0.1414	1.0917
30	0.4700	0.4751	0.310	-0.1414	1.0917
31	-0.7133	.	.	.	.
32	-2.0402	.	.	.	.
33	-1.4697	.	.	.	.
34	-1.3093	.	.	.	.
35	-0.4308	.	.	.	.
36	1.5779	0.7905	0.646	-0.4953	2.0763
37	0.0392	-1.4040	0.476	-2.3514	-0.4565
38	2.1078	0.8736	0.404	0.0682	1.6790

PREDICTION MODEL FOR CLEARING AND GRUBBING

Obs	Dep Var LOG_PR	Predict Value	Std Err Predict	Lower95% Mean	Upper95% Mean
39	2.1078	0.8736	0.404	0.0682	1.6790
40	0.4947	0.8736	0.404	0.0682	1.6790
41	1.8840	0.8736	0.404	0.0682	1.6790
42	-2.0402	-1.9203	0.377	-2.6710	-1.1697
43	-1.7720	-1.9203	0.377	-2.6710	-1.1697
44	-2.0402	-1.9203	0.377	-2.6710	-1.1697
45	-2.0402	-1.9203	0.377	-2.6710	-1.1697
46	-1.2379	-1.9203	0.377	-2.6710	-1.1697
47	0.5306	0.9634	0.227	0.5121	1.4148
48	0	0.9634	0.227	0.5121	1.4148
49	0.5306	0.9634	0.227	0.5121	1.4148
50	0	0.9634	0.227	0.5121	1.4148
51	-0.2877	0.9634	0.227	0.5121	1.4148
52	0.9933	1.0767	0.233	0.6119	1.5415
53	1.5041	1.0767	0.233	0.6119	1.5415
54	-0.1054	1.0767	0.233	0.6119	1.5415
55	0.5878	1.0767	0.233	0.6119	1.5415
56	0.5878	1.0767	0.233	0.6119	1.5415
57	-3.2189	-2.4878	0.331	-3.1480	-1.8275
58	-3.9120	-2.4878	0.331	-3.1480	-1.8275
59	-2.6593	-2.4878	0.331	-3.1480	-1.8275
60	-2.9957	-2.4878	0.331	-3.1480	-1.8275
61	-3.5066	-2.4878	0.331	-3.1480	-1.8275
62	-1.6607	-0.9276	0.397	-1.7175	-0.1376
63	-1.2730	-0.9276	0.397	-1.7175	-0.1376
64	-0.5798	-0.9276	0.397	-1.7175	-0.1376
65	-0.5621	-0.9276	0.397	-1.7175	-0.1376
66	-0.5621	-0.9276	0.397	-1.7175	-0.1376
67	1.6094	1.1192	0.342	0.4376	1.8008
68	1.3863	1.1192	0.342	0.4376	1.8008
69	1.7918	1.1192	0.342	0.4376	1.8008
70	1.6094	1.1192	0.342	0.4376	1.8008
71	1.6094	1.1192	0.342	0.4376	1.8008
72	0.9708	1.4421	0.369	0.7073	2.1769
73	0.9933	1.4421	0.369	0.7073	2.1769
74	-0.6931	1.4421	0.369	0.7073	2.1769
75	1.5728	1.4421	0.369	0.7073	2.1769
76	1.2669	1.4421	0.369	0.7073	2.1769

PREDICTION MODEL FOR CLEARING AND GRUBBING

Obs	Dep Var LOG_PR	Predict Value	Std Err Predict	Lower95% Mean	Upper95% Mean
77	-4.0174	-3.5461	0.637	-4.8143	-2.2780
78	0.8755	-0.0212	0.201	-0.4207	0.3783
79	-0.9163	-0.0212	0.201	-0.4207	0.3783
80	0	-0.0212	0.201	-0.4207	0.3783
81	0.6206	0.2232	0.207	-0.1892	0.6356
82	0.8446	0.2232	0.207	-0.1892	0.6356
83	0.4517	0.2232	0.207	-0.1892	0.6356
84	-1.7260	0.2232	0.207	-0.1892	0.6356
85	-0.1839	0.2232	0.207	-0.1892	0.6356
86	-0.9163	0.2241	0.207	-0.1884	0.6366
87	-0.9163	0.2241	0.207	-0.1884	0.6366
88	0.2624	0.2241	0.207	-0.1884	0.6366
89	-1.2040	0.2241	0.207	-0.1884	0.6366
90	-0.3567	0.2241	0.207	-0.1884	0.6366
91	1.1632	0.5379	0.330	-0.1184	1.1943
92	1.5041	0.5379	0.330	-0.1184	1.1943
93	0.4700	0.5379	0.330	-0.1184	1.1943
94	0.4700	0.5379	0.330	-0.1184	1.1943
95	1.6292	0.5379	0.330	-0.1184	1.1943
96	-1.3863	-2.6057	0.668	-3.9366	-1.2749

Obs	Lower95% Predict	Upper95% Predict	Residual
1	-1.7623	2.0772	-0.1575
2	-1.7623	2.0772	-0.1575
3	-1.7623	2.0772	-0.1575
4	-1.7623	2.0772	-0.1575
5	-1.7623	2.0772	-0.1575
6	-3.5983	0.3786	0.6936
7	0.3410	4.1625	-0.7477
8	0.3410	4.1625	-0.5201
9	0.3410	4.1625	-0.5201
10	0.3410	4.1625	-0.6225
11	-1.6691	1.9958	-0.3377
12	-1.6691	1.9958	1.9136
13	-1.6691	1.9958	1.6082
14	-1.6691	1.9958	0.0678

PREDICTION MODEL FOR CLEARING AND GRUBBING

Obs	Lower95% Predict	Upper95% Predict	Residual
15	-1.6691	1.9958	-1.0308
16	-1.1292	2.5944	0.6024
17	-1.1292	2.5944	1.2484
18	-1.1292	2.5944	1.6824
19	-1.1292	2.5944	1.6025
20	-1.1292	2.5944	1.6025
21	-1.1662	2.7013	0.3311
22	-1.1662	2.7013	0.3311
23	-1.1662	2.7013	0.2070
24	.	.	.
25	.	.	.
26	-1.3957	2.3460	-0.3798
27	-1.3957	2.3460	-0.1387
28	-1.3957	2.3460	-0.2128
29	-1.3957	2.3460	0.0555
30	-1.3957	2.3460	-0.00514
31	.	.	.
32	.	.	.
33	.	.	.
34	.	.	.
35	.	.	.
36	-1.3943	2.9753	0.7875
37	-3.4084	0.6005	1.4432
38	-1.0677	2.8150	1.2342
39	-1.0677	2.8150	1.2342
40	-1.0677	2.8150	-0.3789
41	-1.0677	2.8150	1.0104
42	-3.8396	-0.00107	-0.1199
43	-3.8396	-0.00107	0.1484
44	-3.8396	-0.00107	-0.1199
45	-3.8396	-0.00107	-0.1199
46	-3.8396	-0.00107	0.6825
47	-0.8597	2.7866	-0.4328
48	-0.8597	2.7866	-0.9634
49	-0.8597	2.7866	-0.4328
50	-0.8597	2.7866	-0.9634
51	-0.8597	2.7866	-1.2511
52	-0.7498	2.9032	-0.0834

PREDICTION MODEL FOR CLEARING AND GRUBBING

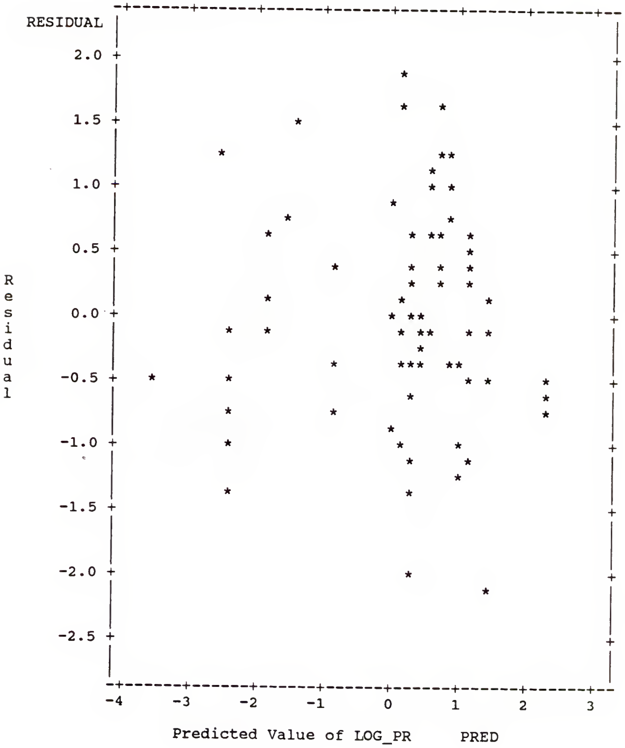
Obs	Lower95% Predict	Upper95% Predict	Residual
53	-0.7498	2.9032	0.4274
54	-0.7498	2.9032	-1.1821
55	-0.7498	2.9032	-0.4889
56	-0.7498	2.9032	-0.4889
57	-4.3735	-0.6020	-0.7311
58	-4.3735	-0.6020	-1.4242
59	-4.3735	-0.6020	-0.1715
60	-4.3735	-0.6020	-0.5080
61	-4.3735	-0.6020	-1.0188
62	-2.8625	1.0074	-0.7332
63	-2.8625	1.0074	-0.3454
64	-2.8625	1.0074	0.3477
65	-2.8625	1.0074	0.3654
66	-2.8625	1.0074	0.3654
67	-0.7741	3.0125	0.4902
68	-0.7741	3.0125	0.2671
69	-0.7741	3.0125	0.6726
70	-0.7741	3.0125	0.4902
71	-0.7741	3.0125	0.4902
72	-0.4710	3.3552	-0.4713
73	-0.4710	3.3552	-0.4488
74	-0.4710	3.3552	-2.1352
75	-0.4710	3.3552	0.1307
76	-0.4710	3.3552	-0.1751
77	-5.7206	-1.3717	-0.4712
78	-1.8322	1.7898	0.8967
79	-1.8322	1.7898	-0.8951
80	-1.8322	1.7898	0.0212
81	-1.5907	2.0370	0.3974
82	-1.5907	2.0370	0.6214
83	-1.5907	2.0370	0.2286
84	-1.5907	2.0370	-1.9491
85	-1.5907	2.0370	-0.4071
86	-1.5898	2.0380	-1.1404
87	-1.5898	2.0380	-1.1404
88	-1.5898	2.0380	0.0382
89	-1.5898	2.0380	-1.4281
90	-1.5898	2.0380	-0.5808

PREDICTION MODEL FOR CLEARING AND GRUBBING

Obs	Lower95% Predict	Upper95% Predict	Residual
91	-1.3465	2.4223	0.6252
92	-1.3465	2.4223	0.9662
93	-1.3465	2.4223	-0.0679
94	-1.3465	2.4223	-0.0679
95	-1.3465	2.4223	1.0913
96	-4.8173	-0.3941	1.2194

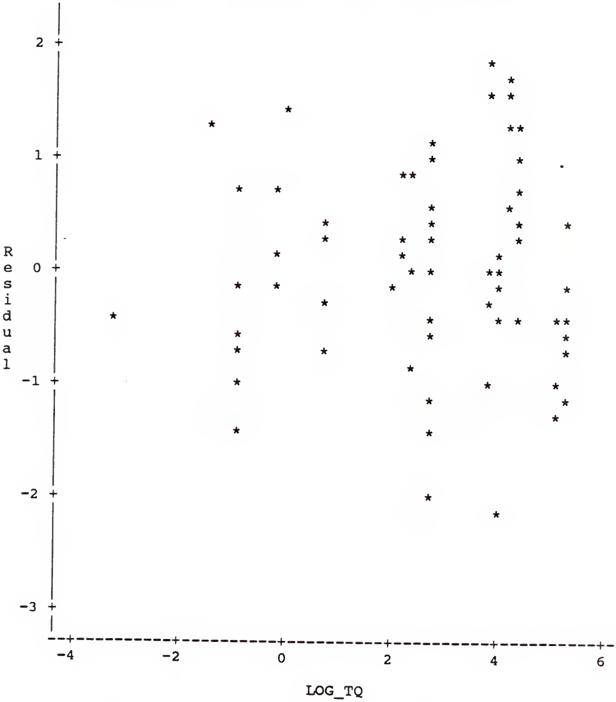
Sum of Residuals	-6.28386E-14
Sum of Squared Residuals	59.7784
Predicted Resid SS (Press)	86.9981

PREDICTION MODEL FOR CLEARING AND GRUBBING



PREDICTION MODEL FOR CLEARING AND GRUBBING

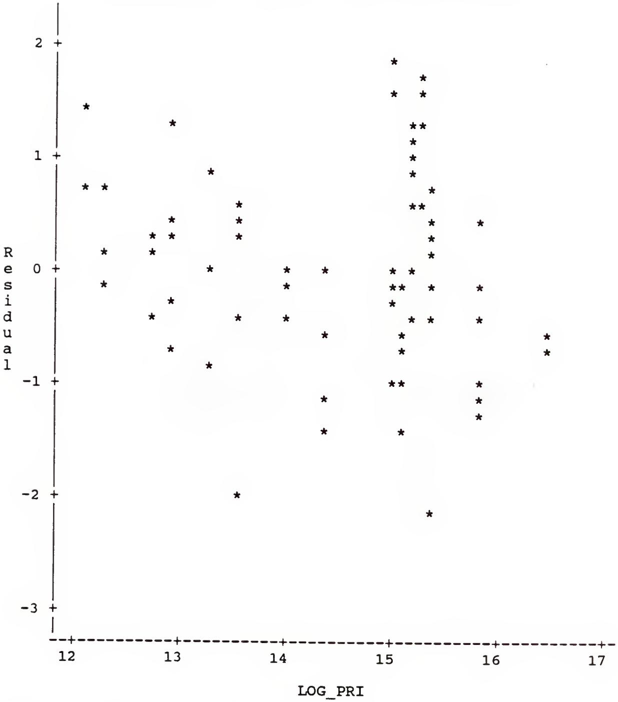
Plot of YRESID*LOG_TQ. Symbol used is '*'.



NOTE: 7 obs had missing values. 26 obs hidden.

PREDICTION MODEL FOR CLEARING AND GRUBBING

Plot of YRESID*LOG_PRI. Symbol used is '*'.



NOTE: 7 obs had missing values. 24 obs hidden.

PREDICTION MODEL FOR CLEARING AND GRUBBING
CONFIDENCE INTERVAL
INDIVIDUAL PREDICTION

OBS	DEP VAR VALUE	PREDICT VALUE	LOWER 95% PRED	UPPER 95% PRED
1	1.000	1.17057	0.17166	7.9824
2	1.000	1.17057	0.17166	7.9824
3	1.000	1.17057	0.17166	7.9824
4	1.000	1.17057	0.17166	7.9824
5	1.000	1.17057	0.17166	7.9824
6	0.400	0.19992	0.02737	1.4602
7	4.500	9.50442	1.40632	64.2344
8	5.650	9.50442	1.40632	64.2344
9	5.650	9.50442	1.40632	64.2344
10	5.100	9.50442	1.40632	64.2344
11	0.840	1.17743	0.18842	7.3579
12	7.980	1.17743	0.18842	7.3579
13	5.880	1.17743	0.18842	7.3579
14	1.260	1.17743	0.18842	7.3579
15	0.420	1.17743	0.18842	7.3579
16	3.800	2.08044	0.32328	13.3886
17	7.250	2.08044	0.32328	13.3886
18	11.190	2.08044	0.32328	13.3886
19	10.330	2.08044	0.32328	13.3886
20	10.330	2.08044	0.32328	13.3886
21	3.000	2.15442	0.31153	14.8990
22	3.000	2.15442	0.31153	14.8990
23	2.650	2.15442	0.31153	14.8990
24	0.100	.	.	.
25	0.120	.	.	.
26	1.100	1.60824	0.24765	10.4439
27	1.400	1.60824	0.24765	10.4439
28	1.300	1.60824	0.24765	10.4439
29	1.700	1.60824	0.24765	10.4439
30	1.600	1.60824	0.24765	10.4439
31	0.490	.	.	.
32	0.130	.	.	.
33	0.230	.	.	.
34	0.270	.	.	.
35	0.650	.	.	.
36	4.845	2.20448	0.24800	19.5957
37	1.040	0.24562	0.03309	1.8230
38	8.230	2.39555	0.34379	16.6925
39	8.230	2.39555	0.34379	16.6925
40	1.640	2.39555	0.34379	16.6925
41	6.580	2.39555	0.34379	16.6925
42	0.130	0.14656	0.02150	0.9989
43	0.170	0.14656	0.02150	0.9989

PREDICTION MODEL FOR CLEARING AND GRUBBING
CONFIDENCE INTERVAL
INDIVIDUAL PREDICTION

OBS	DEP VAR VALUE	PREDICT VALUE	LOWER 95% PRED	UPPER 95% PRED
44	0.130	0.14656	0.02150	0.9989
45	0.130	0.14656	0.02150	0.9989
46	0.290	0.14656	0.02150	0.9989
47	1.700	2.62064	0.42328	16.2250
48	1.000	2.62064	0.42328	16.2250
49	1.700	2.62064	0.42328	16.2250
50	1.000	2.62064	0.42328	16.2250
51	0.750	2.62064	0.42328	16.2250
52	2.700	2.93497	0.47245	18.2326
53	4.500	2.93497	0.47245	18.2326
54	0.900	2.93497	0.47245	18.2326
55	1.800	2.93497	0.47245	18.2326
56	1.800	2.93497	0.47245	18.2326
57	0.040	0.08309	0.01261	0.5477
58	0.020	0.08309	0.01261	0.5477
59	0.070	0.08309	0.01261	0.5477
60	0.050	0.08309	0.01261	0.5477
61	0.030	0.08309	0.01261	0.5477
62	0.190	0.39552	0.05712	2.7385
63	0.280	0.39552	0.05712	2.7385
64	0.560	0.39552	0.05712	2.7385
65	0.570	0.39552	0.05712	2.7385
66	0.570	0.39552	0.05712	2.7385
67	5.000	3.06238	0.46110	20.3389
68	4.000	3.06238	0.46110	20.3389
69	6.000	3.06238	0.46110	20.3389
70	5.000	3.06238	0.46110	20.3389
71	5.000	3.06238	0.46110	20.3389
72	2.640	4.22953	0.62435	28.6521
73	2.700	4.22953	0.62435	28.6521
74	0.500	4.22953	0.62435	28.6521
75	4.820	4.22953	0.62435	28.6521
76	3.550	4.22953	0.62435	28.6521
77	0.018	0.02884	0.00328	0.2537
78	2.400	0.97902	0.16006	5.9883
79	0.400	0.97902	0.16006	5.9883
80	1.000	0.97902	0.16006	5.9883
81	1.860	1.25002	0.20378	7.6679
82	2.327	1.25002	0.20378	7.6679
83	1.571	1.25002	0.20378	7.6679
84	0.178	1.25002	0.20378	7.6679
85	0.832	1.25002	0.20378	7.6679
86	0.400	1.25125	0.20397	7.6756

PREDICTION MODEL FOR CLEARING AND GRUBBING
CONFIDENCE INTERVAL
INDIVIDUAL PREDICTION

OBS	DEP VAR VALUE	PREDICT VALUE	LOWER 95% PRED	UPPER 95% PRED
87	0.40	1.25125	0.20397	7.6756
88	1.30	1.25125	0.20397	7.6756
89	0.30	1.25125	0.20397	7.6756
90	0.70	1.25125	0.20397	7.6756
91	3.20	1.71245	0.26016	11.2719
92	4.50	1.71245	0.26016	11.2719
93	1.60	1.71245	0.26016	11.2719
94	1.60	1.71245	0.26016	11.2719
95	5.10	1.71245	0.26016	11.2719
96	0.25	0.07385	0.00809	0.6743

PREDICTION MODEL FOR CLEARING AND GRUBBING
CONFIDENCE INTERVAL
MEAN

OBS	DEP VAR VALUE	PREDICT VALUE	LOWER 95% MEAN	UPPER 95% MEAN
1	1.000	1.17057	0.55189	2.4828
2	1.000	1.17057	0.55189	2.4828
3	1.000	1.17057	0.55189	2.4828
4	1.000	1.17057	0.55189	2.4828
5	1.000	1.17057	0.55189	2.4828
6	0.400	0.19992	0.08022	0.4982
7	4.500	9.50442	4.58629	19.6965
8	5.650	9.50442	4.58629	19.6965
9	5.650	9.50442	4.58629	19.6965
10	5.100	9.50442	4.58629	19.6965
11	0.840	1.17743	0.72309	1.9172
12	7.980	1.17743	0.72309	1.9172
13	5.880	1.17743	0.72309	1.9172
14	1.260	1.17743	0.72309	1.9172
15	0.420	1.17743	0.72309	1.9172
16	3.800	2.08044	1.15503	3.7473
17	7.250	2.08044	1.15503	3.7473
18	11.190	2.08044	1.15503	3.7473
19	10.330	2.08044	1.15503	3.7473
20	10.330	2.08044	1.15503	3.7473
21	3.000	2.15442	0.98071	4.7328
22	3.000	2.15442	0.98071	4.7328
23	2.650	2.15442	0.98071	4.7328
24	0.100	.	.	.
25	0.120	.	.	.
26	1.100	1.60824	0.86816	2.9792
27	1.400	1.60824	0.86816	2.9792
28	1.300	1.60824	0.86816	2.9792
29	1.700	1.60824	0.86816	2.9792
30	1.600	1.60824	0.86816	2.9792
31	0.490	.	.	.
32	0.130	.	.	.
33	0.230	.	.	.
34	0.270	.	.	.
35	0.650	.	.	.
36	4.845	2.20448	0.60937	7.9750
37	1.040	0.24562	0.09523	0.6335
38	8.230	2.39555	1.07056	5.3604
39	8.230	2.39555	1.07056	5.3604
40	1.640	2.39555	1.07056	5.3604
41	6.580	2.39555	1.07056	5.3604
42	0.130	0.14656	0.06918	0.3105
43	0.170	0.14656	0.06918	0.3105

PREDICTION MODEL FOR CLEARING AND GRUBBING
CONFIDENCE INTERVAL
MEAN

OBS	DEP VAR VALUE	PREDICT VALUE	LOWER 95% MEAN	UPPER 95% MEAN
44	0.130	0.14656	0.06918	0.31047
45	0.130	0.14656	0.06918	0.31047
46	0.290	0.14656	0.06918	0.31047
47	1.700	2.62064	1.66872	4.11558
48	1.000	2.62064	1.66872	4.11558
49	1.700	2.62064	1.66872	4.11558
50	1.000	2.62064	1.66872	4.11558
51	0.750	2.62064	1.66872	4.11558
52	2.700	2.93497	1.84392	4.67162
53	4.500	2.93497	1.84392	4.67162
54	0.900	2.93497	1.84392	4.67162
55	1.800	2.93497	1.84392	4.67162
56	1.800	2.93497	1.84392	4.67162
57	0.040	0.08309	0.04294	0.16081
58	0.020	0.08309	0.04294	0.16081
59	0.070	0.08309	0.04294	0.16081
60	0.050	0.08309	0.04294	0.16081
61	0.030	0.08309	0.04294	0.16081
62	0.190	0.39552	0.17951	0.87145
63	0.280	0.39552	0.17951	0.87145
64	0.560	0.39552	0.17951	0.87145
65	0.570	0.39552	0.17951	0.87145
66	0.570	0.39552	0.17951	0.87145
67	5.000	3.06238	1.54891	6.05469
68	4.000	3.06238	1.54891	6.05469
69	6.000	3.06238	1.54891	6.05469
70	5.000	3.06238	1.54891	6.05469
71	5.000	3.06238	1.54891	6.05469
72	2.640	4.22953	2.02842	8.81916
73	2.700	4.22953	2.02842	8.81916
74	0.500	4.22953	2.02842	8.81916
75	4.820	4.22953	2.02842	8.81916
76	3.550	4.22953	2.02842	8.81916
77	0.018	0.02884	0.00811	0.10249
78	2.400	0.97902	0.65657	1.45984
79	0.400	0.97902	0.65657	1.45984
80	1.000	0.97902	0.65657	1.45984
81	1.860	1.25002	0.82759	1.88807
82	2.327	1.25002	0.82759	1.88807
83	1.571	1.25002	0.82759	1.88807
84	0.178	1.25002	0.82759	1.88807
85	0.832	1.25002	0.82759	1.88807
86	0.400	1.25125	0.82832	1.89011

PREDICTION MODEL FOR CLEARING AND GRUBBING
CONFIDENCE INTERVAL
MEAN

OBS	DEP VAR VALUE	PREDICT VALUE	LOWER 95% MEAN	UPPER 95% MEAN
87	0.40	1.25125	0.82832	1.89011
88	1.30	1.25125	0.82832	1.89011
89	0.30	1.25125	0.82832	1.89011
90	0.70	1.25125	0.82832	1.89011
91	3.20	1.71245	0.88830	3.30123
92	4.50	1.71245	0.88830	3.30123
93	1.60	1.71245	0.88830	3.30123
94	1.60	1.71245	0.88830	3.30123
95	5.10	1.71245	0.88830	3.30123
96	0.25	0.07385	0.01952	0.27945

PREDICTION MODEL FOR EXCAVATION

Model: MODEL1
Dependent Variable: LOG_Q

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	15	167.93139	11.19543	14.300	0.0001
Error	96	75.15946	0.78291		
C Total	111	243.09085			

Root MSE	0.88482	R-square	0.6908
Dep Mean	6.05121	Adj R-sq	0.6425
C.V.	14.62223		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.

```
NB       = 0
LIMITED  = 0
TYP_SUB  = +1.0000 * INTERCEP -1.0000 * TYP_LAT  -1.0000
* TYP_REG
```

PREDICTION MODEL FOR EXCAVATION

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0
INTERCEP	B	5.755543	1.15383762	4.988
LOG_TQ	1	0.437740	0.06741440	6.493
RC	1	-2.554510	0.97370163	-2.624
NB	0	0	0.00000000	.
II	1	-3.820465	1.03950182	-3.675
NC	1	-1.786693	0.99542305	-1.795
SG	1	-2.846023	1.21128889	-2.350
RURAL	1	-0.600389	0.38804644	-1.547
URBAN	1	0.442833	0.39311273	1.126
LIMITED	0	0	0.00000000	.
LIGHT	1	1.242225	0.66366146	1.872
HEAVY	1	-0.943232	0.53831398	-1.752
MEDIUM	1	0.209213	0.52829870	0.396
TYP_LAT	B	0.122206	0.80662778	0.152
TYP_REG	B	-0.339945	0.53058174	-0.641
MAT_SAN	1	-0.733178	0.36182121	-2.026
MAT_ROC	1	-0.569347	0.73862584	-0.771
MAT_MUC	1	-0.058412	0.66913117	-0.087
TYP_SUB	0	0	0.00000000	.

Variable	DF	Prob > |T|
INTERCEP	B	0.0001
LOG_TQ	1	0.0001
RC	1	0.0101
NB	0	.
II	1	0.0004
NC	1	0.0758
SG	1	0.0208
RURAL	1	0.1251
URBAN	1	0.2628
LIMITED	0	.
LIGHT	1	0.0643
HEAVY	1	0.0829
MEDIUM	1	0.6930
TYP_LAT	B	0.8799
TYP_REG	B	0.5232
MAT_SAN	1	0.0455
MAT_ROC	1	0.4427
MAT_MUC	1	0.9306
TYP_SUB	0	.

PREDICTION MODEL FOR BASE

Model: MODEL1
Dependent Variable: LOG_PR

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	13	111.70565	8.59274	6.094	0.0001
Error	119	167.78531	1.40996		
C Total	132	279.49096			

Root MSE	1.18742	R-square	0.3997
Dep Mean	6.68603	Adj R-sq	0.3341
C.V.	17.75968		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.

```
       LIMITED  = 0
       MEDIUM   = +1.0000 * INTERCEP -1.0000 * RC       -1.0000
* NB       -1.0000 * II        -1.0000 * NC        -1.0000 * SG
   +1.0000 * RURAL    +1.0000 * URBAN    -1.0000 * LIGHT
-1.0000 * HEAVY
```

PREDICTION MODEL FOR BASE

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0
INTERCEP	B	3.557789	1.49403559	2.381
LOG_TQ	1	0.333261	0.08751048	3.808
RC	B	1.592424	1.19927021	1.328
NB	B	2.434882	1.62305736	1.500
II	B	0.394522	1.32232460	0.298
NC	B	1.687546	1.31803515	1.280
SG	B	0.931067	1.22972997	0.757
RURAL	B	-1.062293	0.62745081	-1.693
URBAN	B	-1.356593	0.70336046	-1.929
LIMITED	0	0	0.00000000	.
LIGHT	B	0.710581	0.51668602	1.375
HEAVY	B	-0.402573	0.42092363	-0.956
MEDIUM	0	0	0.00000000	.
MAT_S	1	0.435642	0.80627156	0.540
MAT_R	1	-0.697203	0.61044422	-1.142
MAT_A	1	0.175503	0.66527526	0.264

Variable	DF	Prob > |T|
INTERCEP	B	0.0188
LOG_TQ	1	0.0002
RC	B	0.1868
NB	B	0.1362
II	B	0.7660
NC	B	0.2029
SG	B	0.4505
RURAL	B	0.0931
URBAN	B	0.0561
LIMITED	0	.
LIGHT	B	0.1716
HEAVY	B	0.3408
MEDIUM	0	.
MAT_S	1	0.5900
MAT_R	1	0.2557
MAT_A	1	0.7924

PREDICTION MODEL FOR ASPHALT

Model: MODEL1
Dependent Variable: LOG_PR

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	12	179.38968	14.94914	27.549	0.0001
Error	159	86.27924	0.54264		
C Total	171	265.66892			

Root MSE	0.73664	R-square	0.6752
Dep Mean	6.15602	Adj R-sq	0.6507
C.V.	11.96615		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.

SG = 0

PREDICTION MODEL FOR ASPHALT

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0
INTERCEP	1	1.197071	1.01069511	1.184
LOG_TQ	1	0.558623	0.05482873	10.189
RC	1	0.611475	0.60726660	1.007
NB	1	1.194745	0.65508380	1.824
II	1	0.153371	0.65915601	0.233
NC	1	0.070499	0.68073696	0.104
SG	0	0	0.00000000	.
RURAL	1	-0.423256	0.37440741	-1.130
URBAN	1	-0.199363	0.41219455	-0.484
LIGHT	1	0.506167	0.85325634	0.593
HEAVY	1	-0.465685	0.84815043	-0.549
MEDIUM	1	-0.050946	0.82502085	-0.062
LIMITED	1	-0.274218	0.48376369	-0.567
SA	1	-0.221864	0.17256957	-1.286

Variable	DF	Prob > |T|
INTERCEP	1	0.2380
LOG_TQ	1	0.0001
RC	1	0.3155
NB	1	0.0701
II	1	0.8163
NC	1	0.9176
SG	0	.
RURAL	1	0.2600
URBAN	1	0.6293
LIGHT	1	0.5539
HEAVY	1	0.5837
MEDIUM	1	0.9508
LIMITED	1	0.5716
SA	1	0.2004

PREDICTION MODEL FOR STORM DRAINS

Model: MODEL1
Dependent Variable: LOG_PR

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	12	53.30372	4.44198	8.105	0.0001
Error	69	37.81623	0.54806		
C Total	81	91.11995			

Root MSE	0.74031	R-square	0.5850
Dep Mean	3.68330	Adj R-sq	0.5128
C.V.	20.09912		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.

NB = 0

PREDICTION MODEL FOR STORM DRAINS

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0
INTERCEP	1	2.830616	0.94433243	2.997
LOG_TQ	1	0.286849	0.07693538	3.728
RC	1	-0.128761	0.51101104	-0.252
NB	0	0	0.00000000	.
II	1	-0.219912	0.75908999	-0.290
NC	1	-0.191264	0.68748899	-0.278
SG	1	-1.298789	0.60321362	-2.153
RURAL	1	-0.146479	0.46762328	-0.313
URBAN	1	-0.115760	0.40123196	-0.289
HEAVY	1	-0.002649	0.84882994	-0.003
MEDIUM	1	0.223525	0.81835320	0.273
LIGHT	1	-0.461404	0.97466863	-0.473
DIA	1	-0.029787	0.01083138	-2.750
DEPTH	1	0.026092	0.09334668	0.280

Variable	DF	Prob > |T|
INTERCEP	1	0.0038
LOG_TQ	1	0.0004
RC	1	0.8018
NB	0	.
II	1	0.7729
NC	1	0.7817
SG	1	0.0348
RURAL	1	0.7550
URBAN	1	0.7738
HEAVY	1	0.9975
MEDIUM	1	0.7856
LIGHT	1	0.6374
DIA	1	0.0076
DEPTH	1	0.7807

APPENDIX D

COMPUTER SOURCE CODE

```
*LAB1;
PROC PRINT  DATA = PHD.CLEAR4 SPLIT = '*';

 TITLE 'DATA SET FOR CLEARING AND GRUBBING';
 LABEL

JOB_NO     =    'PROJECT*NUMBER'
PROD_RT    =    'PRODUCTION RATE*ACRES/DAY'
TOT_QTY    =    'F1'
PRICE      =    'F2'
RC         =    'F3'
NB         =    'F4'
II         =    'F5'
NC         =    'F6'
SG         =    'F7'
RURAL      =    'F8'
URBAN      =    'F9'
LIMITED    =    'F10'
LIGHT      =    'F11'
MEDIUM     =    'F12'
HEAVY      =    'F13'
TYP_L      =    'C1'
TYP_M      =    'C2'
TYP_H      =    'C3'
;
    VAR
JOB_NO
PROD_RT
TOT_QTY
PRICE
RC
NB
II
NC
SG
RURAL
URBAN
LIMITED
LIGHT
MEDIUM
HEAVY

TYP_L
TYP_M
TYP_H
;
RUN;

PROC PRINT  DATA = PHD.EXCAV4 SPLIT = '*';

 TITLE 'DATA SET FOR EXCAVATION';
 LABEL
```

```
JOB_NO     =    'PROJECT*NUMBER'
QTY        =    'PRODUCTION RATE*CY/DAY'
TOTQTY     =    'F1'
PRICE      =    'F2'
RC         =    'F3'
NB         =    'F4'
II         =    'F5'
NC         =    'F6'
SG         =    'F7'
RURAL      =    'F8'
URBAN      =    'F9'
LIMITED    =    'F10'
LIGHT      =    'F11'
MEDIUM     =    'F12'
HEAVY      =    'F13'
TYP_REG    =    'E1'
TYP_LAT    =    'E2'
TYP_SUB    =    'E3'
MAT_SAN    =    'E4'
MAT_ROC    =    'E5'
MAT_MUC    =    'E6'
;
    VAR
JOB_NO
QTY
TOTQTY
PRICE
RC
NB
II
NC
SG
RURAL
URBAN
LIMITED
LIGHT
MEDIUM
HEAVY

TYP_REG
TYP_LAT
TYP_SUB
MAT_SAN
MAT_ROC
MAT_MUC
;
RUN;

PROC PRINT  DATA = PHD.BASE4 SPLIT = '*';
*LAB3;
 TITLE 'DATA SET FOR BASE';
 LABEL
```

```
JOB_NO     =    'PROJECT*NUMBER'
PROD_RT    =    'PRODUCTION RATE*SY/DAY'
TOT_QTY    =    'F1'
PRICE      =    'F2'
RC         =    'F3'
NB         =    'F4'
II         =    'F5'
NC         =    'F6'
SG         =    'F7'
RURAL     '=    'F8'
URBAN      =    'F9'
LIMITED    =    'F10'
LIGHT      =    'F11'
MEDIUM     =    'F12'
HEAVY      =    'F13'
MAT_S      =    'B1'
MAT_R      =    'B2'
MAT_A      =    'B3'
;
    VAR
JOB_NO
PROD_RT
TOT_QTY
PRICE
RC
NB
II
NC
SG
RURAL
URBAN
LIMITED
LIGHT
MEDIUM
HEAVY

MAT_S
MAT_R
MAT_A
;
RUN;

*LAB6;
PROC PRINT  DATA = PHD.ASPHALT5 SPLIT = '*';
 TITLE 'DATA SET FOR ASPHALT PAVEMENT' ;
 LABEL

JOB_NO     =    'PROJECT*NUMBER'
PROD_RT    =    'PRODUCTION RATE*TN/DAY'
TOT_QTY    =    'F1'
PRICE      =    'F2'
RC         =    'F3'
NB         =    'F4'
II         =    'F5'
```

```
NC          =    'F6'
SG          =    'F7'
RURAL       =    'F8'
URBAN       =    'F9'
LIMITED     =    'F10'
LIGHT       =    'F11'
MEDIUM      =    'F12'
HEAVY       =    'F13'
SM_AREA     =    'A1'
;
    VAR
JOB_NO
PROD_RT
TOT_QTY
PRICE
RC
NB
II
NC
SG
RURAL
URBAN
LIMITED
LIGHT
MEDIUM
HEAVY
SM_AREA
;
RUN;

*LAB7;
PROC PRINT  DATA = PHD.STORM5 SPLIT = '*';
 TITLE 'DATA SET FOR STORM DRAIN' ;
 LABEL

JOB_NO      =    'PROJECT*NUMBER'
PROD_RT     =    'PRODUCTION RATE*LF/DAY'
TOT_QTY     =    'F1'
PRICE       =    'F2'
RC          =    'F3'
NB          =    'F4'
II          =    'F5'
NC          =    'F6'
SG          =    'F7'
RURAL       =    'F8'
URBAN       =    'F9'
LIMITED     =    'F10'
LIGHT       =    'F11'
MEDIUM      =    'F12'
HEAVY       =    'F13'
DEPTH       =    'ST1'
DIA         =    'ST2'
;
```

```
    VAR
JOB_NO
PROD_RT
TOT_QTY
PRICE
RC
NB
II
NC
SG
RURAL
URBAN
LIMITED
LIGHT
MEDIUM
HEAVY
DEPTH
DIA
;
RUN;

PROC REG   DATA = PHD.CLEAR4;
   MODEL PROD_RT =
TOT_QTY PRICE RC NB II NC SG RURAL URBAN LIMITED

LIGHT MEDIUM HEAVY  TOT_QTY2
TYP_L TYP_M TYP_H
/ SELECTION=MAXR  CP
  ;
RUN;

PROC REG   DATA = PHD.CLEAR4;
   MODEL PROD_RT =
TOT_QTY PRICE RC NB II NC    RURAL URBAN LIMITED

LIGHT MEDIUM        TOT_QTY2
      TYP_M TYP_H
/   CP P
  ;
OUTPUT OUT=REG1_OUT
P=YHAT
R=YRESID;

PLOT RESIDUAL.*PREDICTED.='*';
TITLE 'PREDICTION MODEL FOR CLEAR AND GRUBB';
RUN;

PROC PLOT DATA= REG1_OUT;
PLOT YRESID*TOT_QTY='*';
PLOT YRESID*TOT_QTY2='*';
PLOT YRESID*PRICE='*';
RUN;

PROC REG   DATA = PHD.CLEAR4;
```

```
   MODEL LOG_PR  =
LOG_TQ  LOG_PRI  RC  NB  II  NC  SG  RURAL  URBAN
LIMITED
LIGHT MEDIUM HEAVY  LOG_TQ2
TYP_L TYP_M TYP_H
INAC_LH INAC_LM INAC_LL
INAC_UH INAC_UM INAC_UL
INAC_RH INAC_RM INAC_RL
/ SELECTION=MAXR  CP
  ;
RUN;

PROC REG   DATA = PHD.CLEAR5;
   MODEL LOG_PR  =
LOG_TQ          RC NB II NC SG
LIGHT        MEDIUM  HEAVY
TYP_M   TYP_H
RURAL URBAN LIMITED

/   CP P CLM CLI
  ;
OUTPUT OUT=REG2_OUT
P=YHAT
R=YRESID
L95M =L95M
U95M =U95M
L95  =L95
U95  =U95
;

PLOT RESIDUAL.*PREDICTED.='*';
TITLE  'PREDICTION  MODEL  FOR  CLEARING  AND
GRUBBING';
RUN;

PROC PLOT DATA= REG2_OUT;
PLOT YRESID*LOG_TQ='*';
PLOT YRESID*LOG_PRI='*';
RUN;

DATA TRANS ;
SET REG2_OUT;
YHAT = EXP(YHAT);
L95 = EXP(L95);
L95M = EXP(L95M);
U95M = EXP(U95M);
U95 = EXP(U95)    ;
YRESID= EXP(YRESID);
RUN;

PROC PRINT DATA = TRANS SPLIT='*';
VAR PROD_RT YHAT L95   U95  ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'INDIVIDUAL PREDICTION';
```

```
LABEL
PROD_RT ='DEP VAR*VALUE'
YHAT    ='PREDICT*VALUE'
L95     ='LOWER 95%*PRED'
U95     ='UPPER 95%*PRED';
RUN;
PROC PRINT DATA = TRANS SPLIT='*';
VAR PROD_RT YHAT L95M   U95M ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'MEAN';
LABEL
PROD_RT      ='DEP VAR*VALUE'
YHAT    ='PREDICT*VALUE'
L95M    ='LOWER 95%*MEAN'
U95M    ='UPPER 95%*MEAN';
RUN;

DATA PHD.EXCAV5;
SET PHD.EXCAV5 ;
INAC_LH = LIMITED *HEAVY;
INAC_LM = LIMITED *MEDIUM;
INAC_LL = LIMITED *LIGHT;
INAC_UH = URBAN   *HEAVY;
INAC_UM = URBAN   *MEDIUM;
INAC_UL = URBAN   *LIGHT;
INAC_RH = RURAL   *HEAVY;
INAC_RM = RURAL   *MEDIUM;
INAC_RL = RURAL   *LIGHT;
LOG_Q   = LOG(QTY);
LOG_TQ   = LOG(TOTQTY);
LOG_PRI= LOG(PRICE);
LOG_TQ2= LOG(TOTQTY2);
RUN;
PROC REG   DATA = PHD.EXCAV5;
   MODEL LOG_Q   =
LOG_TQ  LOG_PRI  RC  NB  II  NC  SG  RURAL  URBAN
LIMITED
LIGHT MEDIUM HEAVY  LOG_TQ2
TYP_LAT TYP_SUB TYP_REG MAT_SAN MAT_ROC MAT_MUC
INAC_LH INAC_LM INAC_LL
INAC_UH INAC_UM INAC_UL
INAC_RH INAC_RM INAC_RL
/ SELECTION=MAXR  CP
TITLE 'MODEL SELECTION  EXCAVATION';
  ;
RUN;

PROC REG   DATA = PHD.EXCAV5;
   MODEL LOG_Q   =
LOG_TQ              RC  NB  II  NC  SG  RURAL   URBAN
LIMITED
LIGHT HEAVY  MEDIUM
TYP_LAT TYP_REG MAT_SAN MAT_ROC MAT_MUC TYP_SUB
```

```
/   CP P CLM CLI
  ;
OUTPUT OUT=REG2_OUT
P=YHAT
R=YRESID
L95M =L95M
U95M =U95M
L95  =L95
U95  =U95
;

PLOT RESIDUAL.*PREDICTED.='*';
TITLE 'PREDICTION MODEL FOR EXCAVATION';
RUN;

PROC PLOT DATA= REG2_OUT;
PLOT YRESID*LOG_TQ='*';
RUN;

DATA TRANS ;
SET REG2_OUT;
YHAT = EXP(YHAT);
L95 = EXP(L95);
L95M = EXP(L95M);
U95M = EXP(U95M);
U95 = EXP(U95)     ;
YRESID= EXP(YRESID);
RUN;

PROC PRINT DATA = TRANS SPLIT='*';
VAR QTY YHAT L95   U95  ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'INDIVIDUAL PREDICTION';
LABEL
QTY      ='DEP VAR*VALUE'
YHAT     ='PREDICT*VALUE'
L95      ='LOWER 95%*PRED'
U95      ='UPPER 95%*PRED';
RUN;
PROC PRINT DATA = TRANS SPLIT='*';
VAR QTY YHAT L95M   U95M ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'MEAN';
LABEL
QTY      ='DEP VAR*VALUE'
YHAT     ='PREDICT*VALUE'
L95M     ='LOWER 95%*MEAN'
U95M     ='UPPER 95%*MEAN';
RUN;

DATA PHD.BASE5;
SET PHD.BASE5 ;
INAC_LH = LIMITED *HEAVY;
INAC_LM = LIMITED *MEDIUM;
```

```
INAC_LL = LIMITED *LIGHT;
INAC_UH = URBAN   *HEAVY;
INAC_UM = URBAN   *MEDIUM;
INAC_UL = URBAN   *LIGHT;
INAC_RH = RURAL   *HEAVY;
INAC_RM = RURAL   *MEDIUM;
INAC_RL = RURAL   *LIGHT;
TOT_QTY2 = TOT_QTY * TOT_QTY;
LOG_PR  = LOG(PROD_RT);
LOG_TQ  = LOG(TOT_QTY);
LOG_PRI= LOG(PRICE);
LOG_TQ2= LOG(TOT_QTY2);
RUN;
PROC REG   DATA = PHD.BASE5;
   MODEL LOG_PR  =
LOG_TQ  LOG_PRI  RC  NB  II  NC  SG  RURAL  URBAN
LIMITED
LIGHT MEDIUM HEAVY  LOG_TQ2
MAT_S MAT_R MAT_A
INAC_LH INAC_LM INAC_LL
INAC_UH INAC_UM INAC_UL
INAC_RH INAC_RM INAC_RL
/ SELECTION=RMAX CP;
TITLE 'MODEL SELECTION  BASE ';
RUN;

PROC REG   DATA = PHD.BASE5;
   MODEL LOG_PR  =
LOG_TQ               RC  NB  II  NC  SG  RURAL  URBAN
LIMITED
LIGHT HEAVY MEDIUM
MAT_S MAT_R   MAT_A


/   CP P CLM CLI
  ;
OUTPUT OUT=REG1_OUT
P=YHAT
R=YRESID
L95M =L95M
U95M =U95M
L95  =L95
U95  =U95
;

PLOT RESIDUAL.*PREDICTED.='*';
TITLE 'PREDICTION MODEL FOR BASE';
RUN;

PROC PLOT DATA= REG1_OUT;
PLOT YRESID*LOG_TQ='*';
PLOT YRESID*LOG_PRI='*';
RUN;
```

```
DATA TRANS ;
SET REG1_OUT;
YHAT = EXP(YHAT);
L95 = EXP(L95);
L95M = EXP(L95M);
U95M = EXP(U95M);
U95 = EXP(U95)    ;

YRESID= EXP(YRESID);
RUN;

PROC PRINT DATA = TRANS SPLIT='*';
VAR PROD_RT YHAT L95   U95  ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'INDIVIDUAL PREDICTION';
LABEL
PROD_RT ='DEP VAR*VALUE'
YHAT    ='PREDICT*VALUE'
L95     ='LOWER 95%*PRED'
U95     ='UPPER 95%*PRED';
RUN;
PROC PRINT DATA = TRANS SPLIT='*';
VAR PROD_RT YHAT L95M   U95M ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'MEAN';
LABEL
PROD_RT ='DEP VAR*VALUE'
YHAT    ='PREDICT*VALUE'
L95M    ='LOWER 95%*MEAN'
U95M    ='UPPER 95%*MEAN';
RUN;

DATA PHD.ASPHALT6;
SET PHD.ASPHALT6;
INAC_LH = LIMITED *HEAVY;
INAC_LM = LIMITED *MEDIUM;
INAC_LL = LIMITED *LIGHT;
INAC_UH = URBAN   *HEAVY;
INAC_UM = URBAN   *MEDIUM;
INAC_UL = URBAN   *LIGHT;
INAC_RH = RURAL   *HEAVY;
INAC_RM = RURAL   *MEDIUM;
INAC_RL = RURAL   *LIGHT;
TOT_QTY2 = TOT_QTY * TOT_QTY;
LOG_PR  = LOG(PROD_RT);
LOG_TQ  = LOG(TOT_QTY);
LOG_PRI= LOG(PRICE);
LOG_TQ2= LOG(TOT_QTY2);
RUN;
PROC REG   DATA = PHD.ASPHALT6;
   MODEL LOG_PR  =
LOG_TQ  LOG_PRI  RC  NB  II  NC  SG  RURAL  URBAN
LIMITED
LIGHT MEDIUM HEAVY  LOG_TQ2
```

```
SM_AREA
INAC_LH INAC_LM INAC_LL
INAC_UH INAC_UM INAC_UL
INAC_RH INAC_RM INAC_RL
/ SELECTION=MAXR CP;
TITLE 'MODEL SELECTION  ASPHALT';
RUN;

PROC REG   DATA = PHD.ASPHALT6;
   MODEL LOG_PR  =
LOG_TQ        RC  NB II NC SG RURAL URBAN
LIGHT HEAVY MEDIUM  LIMITED
SA


/   CP P CLM CLI
  ;
OUTPUT OUT=REG1_OUT
P=YHAT
R=YRESID
L95M =L95M
U95M =U95M
L95  =L95
U95  =U95
;

PLOT RESIDUAL.*PREDICTED.='*';
TITLE 'PREDICTION MODEL FOR ASPHALT';
RUN;

PROC PLOT DATA= REG1_OUT;
PLOT YRESID*LOG_TQ='*';
PLOT YRESID*LOG_PRI='*';
RUN;

DATA TRANS ;
SET REG1_OUT;
YHAT = EXP(YHAT);
L95 = EXP(L95);
L95M = EXP(L95M);
U95M = EXP(U95M);
U95 = EXP(U95)    ;
YRESID= EXP(YRESID);
RUN;

PROC PRINT DATA = TRANS SPLIT='*';
VAR PROD_RT YHAT L95   U95  ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'INDIVIDUAL PREDICTION';
LABEL
PROD_RT ='DEP VAR*VALUE'
YHAT    ='PREDICT*VALUE'
L95     ='LOWER 95%*PRED'
U95     ='UPPER 95%*PRED';
```

```
RUN;
PROC PRINT DATA = TRANS SPLIT='*';
VAR PROD_RT YHAT L95M   U95M ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'MEAN';
LABEL
PROD_RT ='DEP VAR*VALUE'
YHAT    ='PREDICT*VALUE'
L95M    ='LOWER 95%*MEAN'
U95M    ='UPPER 95%*MEAN';
RUN;

DATA PHD.STORM6;
SET PHD.STORM6 ;
INAC_LH = LIMITED *HEAVY;
INAC_LM = LIMITED *MEDIUM;
INAC_LL = LIMITED *LIGHT;
INAC_UH = URBAN   *HEAVY;
INAC_UM = URBAN   *MEDIUM;
INAC_UL = URBAN   *LIGHT;
INAC_RH = RURAL   *HEAVY;
INAC_RM = RURAL   *MEDIUM;
INAC_RL = RURAL   *LIGHT;
TOT_QTY2 = TOT_QTY * TOT_QTY;
LOG_PR  = LOG(PROD_RT);
LOG_TQ  = LOG(TOT_QTY);
LOG_PRI= LOG(PRICE);
LOG_TQ2= LOG(TOT_QTY2);
RUN;
PROC REG   DATA = PHD.STORM6;
   MODEL LOG_PR  =
LOG_TQ  LOG_PRI  RC  NB  II  NC  SG  RURAL  URBAN
LIMITED
LIGHT MEDIUM HEAVY  LOG_TQ2
DEPTH DIA
INAC_LH INAC_LM INAC_LL
INAC_UH INAC_UM INAC_UL
INAC_RH INAC_RM INAC_RL
/ SELECTION=MAXR CP;
TITLE 'MODEL SELECTION  STORM DRAINS ';
RUN;

PROC REG   DATA = PHD.STORM6;
   MODEL LOG_PR  =
LOG_TQ LOG_PRI RC    II NC SG RURAL URBAN
     HEAVY MEDIUM
DIA  INAC_UH INAC_RH INAC_RL


/   CP P CLM CLI
  ;
OUTPUT OUT=REG1_OUT
P=YHAT
R=YRESID
```

```
L95M =L95M
U95M =U95M
L95  =L95
U95  =U95
;

PLOT RESIDUAL.*PREDICTED.='*';
TITLE 'PREDICTION MODEL FOR STORM DRAINS';
RUN;

PROC PLOT DATA= REG1_OUT;
PLOT YRESID*LOG_TQ='*';
PLOT YRESID*LOG_PRI='*';
PLOT YRESID*DIA='*';
RUN;

DATA TRANS ;
SET REG1_OUT;
YHAT = EXP(YHAT);
L95 = EXP(L95);
L95M = EXP(L95M);
U95M = EXP(U95M);
U95 = EXP(U95)    ;
YRESID= EXP(YRESID);
RUN;

PROC PRINT DATA = TRANS SPLIT='*';
VAR PROD_RT YHAT L95   U95  ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'INDIVIDUAL PREDICTION';
LABEL
PROD_RT ='DEP VAR*VALUE'
YHAT    ='PREDICT*VALUE'
L95     ='LOWER 95%*PRED'
U95     ='UPPER 95%*PRED';
RUN;
PROC PRINT DATA = TRANS SPLIT='*';
VAR PROD_RT YHAT L95M   U95M ;
TITLE2 'CONFIDENCE INTERVAL';
TITLE3 'MEAN';
LABEL
PROD_RT ='DEP VAR*VALUE'
YHAT    ='PREDICT*VALUE'
L95M    ='LOWER 95%*MEAN'
U95M    ='UPPER 95%*MEAN';
RUN;
```

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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